Technical Report 647

The Development of the Army's Enlisted Personnel Allocation System

Edward J. Schmitz and Roy D. Nord
Army Research Institute

and

Peter B. McWhite, George N. Brown, Elizabeth A. Gilmore, Frank P. Konieczny, David W. Moore, Murray J. Randall, Gerald E. Paul and David A. Smyre
General Research Corporation

Manpower and Personnel Policy Research Group
Manpower and Personnel Research Laboratory

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EDGAR M. JOHNSON
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

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General Research Corporation

Technical review by

Hyder Lakhani
Rebecca Pliske

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The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is undertaking a comprehensive research program to improve the selection, classification, and allocation of Army personnel. A key part of this program is the Enlisted Personnel Allocation System (EPAS), which is being developed by ARI with the support of the General Research Corporation. EPAS will improve personnel performance by achieving a better match between the Army's requirements and the capabilities of the people applying for service. (Continued)

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20. (Continued)

This report discusses the development of the EPAS version for allocating nonprior service accessions to training for their military occupational specialties (MOSs). (Other versions will allocate reenlistees, retrainees, reclassifications, and prior service accessions.) The system described is a prototype of the final EPAS. It contains all the features but has less detail. This system is particularly useful for performing policy analysis and selection and classification experiments.

EPAS makes extensive use of operations research techniques. It comprises modules that perform forecasting of nonprior service accessions, large-scale network optimization of assignments to MOS, and policy specifying to aid the recruiter and applicant in their final selection of an MOS.

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7. Authors (continued)

Murray J. Randall, Gerald E. Paul and David A. Smyre (General Research Corporation).

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General Research Corporation

Submitted by
Curtis Gilroy, Chief
Manpower and Personnel Policy Research Group

Approved as technically adequate
and submitted for publication by
Joyce L. Shields, Director
Manpower and Personnel
Research Laboratory

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is undertaking a comprehensive research program to improve the selection, classification, and allocation of Army personnel. A key part of this program is the Enlisted Personnel Allocation System (EPAS). EPAS will improve personnel performance by achieving a better match between the Army's requirements and the capabilities of the people applying for service. This report describes an operational prototype of EPAS.

EDGAR M. JOHNSON
Technical Director

THE DEVELOPMENT OF THE ARMY'S ENLISTED PERSONNEL ALLOCATION SYSTEM

EXECUTIVE SUMMARY

Requirement:

The Army's present person-job-match system has substantial opportunities for improvement. These include assigning more enlistees to jobs that maximize their expected performance and minimize their attrition, using distributed processing, and holding open selected jobs that can attract high-quality applicants. In addition, a key requirement is to look ahead at the supply of applicants and the job training requirements to avoid problems or estimate how policy changes will affect the supply and distribution of personnel.

Procedure:

The authors are developing a decision support system (DSS) incorporating advanced operations research techniques to improve the Army's person-job-match capabilities. Called the Enlisted Personnel Allocation System (EPAS), it integrates time series forecasting, large-scale linear optimization, and policy-specifying techniques. Because of the complexity of this effort, the authors first developed a reduced-scale prototype to evaluate their systems design.

Findings:

The prototype system validated the EPAS design. The prototype demonstrates the feasibility of using this complex DSS to guide Army guidance counselors' classification decisions and to evaluate recruiting strategies. EPAS represents a significant improvement over current person-job-match systems.

Utilization of Findings:

The present work has provided a sound justification for continuing EPAS development. Experiments should be conducted to further delineate EPAS's capabilities and to assess policy alternatives using EPAS. Plans for implementation by the Army should proceed.

THE DEVELOPMENT OF THE ARMY'S ENLISTED PERSONNEL ALLOCATION SYSTEM

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I. INTRODUCTION TO THE ENLISTED PERSONNEL ALLOCATION SYSTEM

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is undertaking a comprehensive research program to improve the selection, classification, and allocation of Army personnel. A key part of this program is the Enlisted Personnel Allocation System (EPAS), which is being developed by ARI with the support of the General Research Corporation (GRC). EPAS will improve personnel performance by achieving a better match between the Army's requirements and the capabilities of the people applying for service.

This research report discusses the development of the EPAS version for allocating nonprior service accessions to training for their military occupational specialties (MOSs). (Other versions will allocate reenlistees, retrainees, reclassifications, and prior service accessions.) This version is being developed first because it is the most difficult and most important version. It is difficult because the Army has less knowledge about nonprior service applicants than about other groups being allocated. It is important because nonprior service applicants form the largest category of personnel to be allocated (150,000 per year) and have the most flexibility for allocation.

The system described here is a prototype of the final EPAS. (The report describes the system that existed in May 1984.) The prototype performs all the operations of the full system, but contains less detail than the final version. The basic methodologies will be similar, but the prototype is smaller and easier to modify. Also, the prototype system is particularly useful for performing policy analysis and selection and classification experiments.

This report comprises four major sections. The remainder of this section provides an overview of personnel allocation problems and the general approach being used in EPAS to solve these problems. Section II describes in detail the management science applications being developed for EPAS. Section III discusses the ADP implementation of the prototype system, including a discussion

of the kinds of simulations that can be readily performed with this version. The final section provides some examples of preliminary EPAS test runs that indicate how the impact of specific modules or the entire system can be evaluated.

The Enlistment Process

Every year, over 300,000 people apply to join the Army. Figure 1 illustrates the major steps an applicant goes through in the enlistment process. The applicant first takes the Armed Services Vocational Aptitude Battery (ASVAB) to determine if he is mentally qualified to enter the Army. This is followed by a physical examination. After satisfying the mental, physical, and moral standards, the applicant is offered a job assignment by an Army guidance counselor and signs an enlistment contract. He then returns home until it is time to report for active duty (up to 12 months in the future). This time, between contract signing and reporting for active duty, is permitted by the Delayed Entry Program (DEP).

The signing of the enlistment contract is a key decision point in an applicant's Army career. Applicants are guaranteed the kind of training they will receive at this time, even though it may be over a year before they actually report for active duty and their military occupational specialty (MOS) training.

While the guarantee of specific job training is a useful recruiting tool for the Army, it creates a number of management problems. These include:

- Filling yearly job requirements.
- Keeping specific job classes from becoming too large or too small.
- Keeping popular jobs from being "sold out" to marginally qualified candidates.

ARMY PERSONNEL ACCESSION FLOW

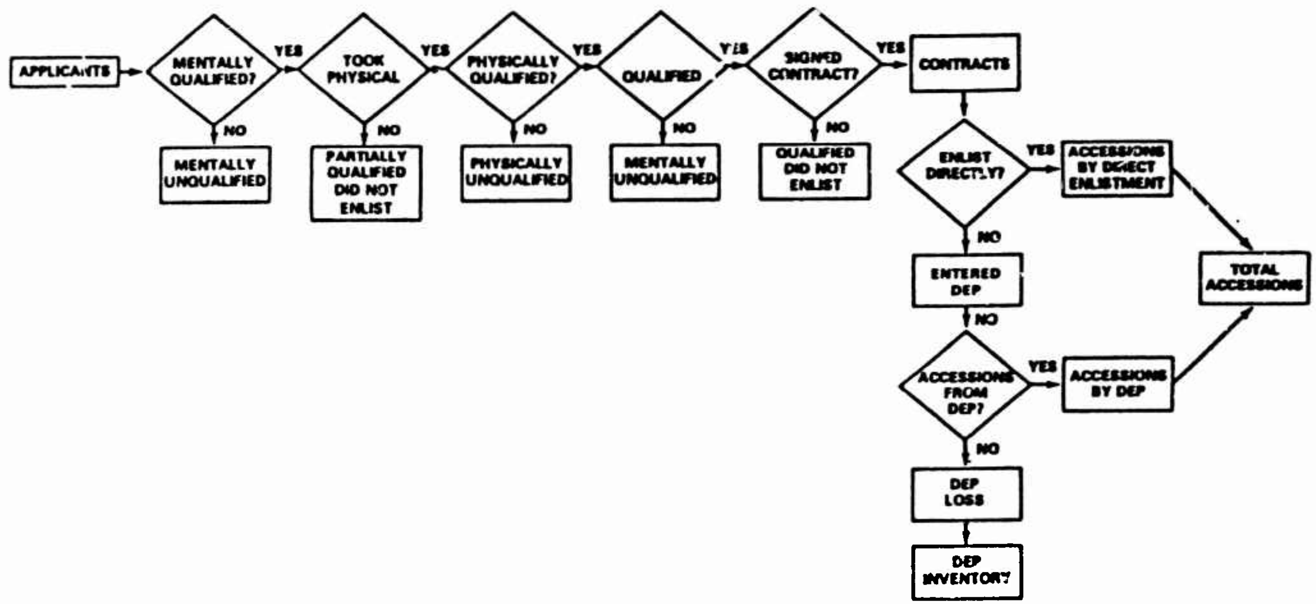

Figure 1. Army Personnel Accession Flow

- Assuring a supply of desirable jobs to attract highly talented people.

The Army's present person-job match system's goal is to fill all open job requirements, but does not make trade-offs between other important objectives such as minimizing attrition and maximizing job performance. While it permits a satisfactory match of applicants with jobs, there are substantial opportunities for improvement. These include:

- Over 80% of enlistees do not train for a job which would use their strongest aptitude.
- Enlistees are not matched to jobs that would minimize their attrition during the first term of service (normally 3 years).
- Distributed processing is not used; time sharing costs are $25 to $30 million per year.
- Nearly half of the most desirable applicants (high school graduate males with above average Armed Forces Qualification Test (AFQT) scores) fail to sign enlistment contracts.

These problems are symptomatic of the limited planning capabilities of the present allocation process. There is no capacity to "look ahead" and take corrective actions to avoid problems, or estimate how policy changes will affect the supply and distribution of personnel. The next section describes the nature of the management science problem.

The Enlisted Personnel Allocation Technical Problem

The assignment of applicants to jobs has long been known as an area of management science application. The problem of assigning applicants to jobs can be formulated as:

$$\text{maximize} \qquad Z = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} \; X_{ij}$$

$$\text{subject to:} \qquad \sum_{i=1}^{n} X_{ij} = 1$$

$$\sum_{j=1}^{n} X_{ij} = 1$$

The objective is to maximize the weighted assignment of a group of i applicants to j jobs, subject to constraints that each applicant is assigned, and each job is filled. The weight, $c_{i,j}$, represents a figure of merit for assigning applicant i to job type j.

This kind of personnel assignment problem has been an early area for the application of efficient algorithms, including network flow models (see Kuhn 1955; Ford and Fulkerson 1962). Others have shown how to reduce related problems to this formulation (Charnes and Cooper 1961; Hillier and Lieberman 1967).

However, the Army's problem is more complicated because:

- Applicants must be offered jobs sequentially, rather than in a batch.
- The applicant may choose not to take the optimal assignment.
- There are multiple "figures of merit" or performance-cost measures for each possible assignment.
- The DEP creates a multiperiod problem, since applicants can be assigned a training seat (which determines their active duty date) in several different time periods.

- The supply of applicants will vary over time due to various seasonal, economic, demographic, and policy changes.

The Army cannot process groups of applicants as a batch. Rather, each must be sequentially assigned to an MOS. An applicant must be offered an enlistment contract while he meets with a recruiting guidance counselor (generally, for no more than 15 minutes).

Also, unlike many personnel selection and assignment problems, (Hatch 1971; Hunter and Schmidt 1982), there is no guarantee that applicants will accept the optimal assignment. In fact, recent analysis have shown that 48% of the high quality applicants (high school graduate males with above average aptitude) have failed to sign contracts (Schmitz and Nelson 1984). Operationally, there is a need to provide flexibility in the negotiation of the enlistment contract. High quality people who have the option to go elsewhere need to be offered desirable assignments; others should be permitted to enlist in assignments specified by the Army.

In traditional assignment problems there is usually a single measure of merit $c_{i,j}$ to be optimized. This may be the probability of job success, training cost, or another performance measure (Dunnette, 1966). However, in the Army's allocation system there is no single $c_{i,j}$ measured to be optimized. Rather, there are several goals that need to be solved for simultaneously, including:

- Maximize job performance. Schmitz and Nelson (1984) demonstrated that an "optimum" set of job assignments can increase soldiers' performance test scores.
- Maximize expected service time. Nelson and Schmitz (1984) demonstrated that "optimum" job assignments can also reduce attrition.

- Provide job fill priority. If it is not possible to fill all job training openings, the system must ensure fill of high priority jobs, such as those in the combat arms.
- Maximize reenlistment potential. Assignments to each job field should ensure that applicants will have a sufficient propensity to reenlist for a second term of service.

The Army's DEP creates a more complex management science problem, but also provides additional solution flexibility. For example, it permits scheduling an applicant who is expected to make an outstanding electronics technician into the time period where such training seats are available. While models have been developed to address these problems (Charnes 1972), the empirical solution of such problems can be formidable.

The supply of applicants is a major factor in personnel allocation planning. Given a multiperiod distribution problem, it is extremely sensible to incorporate multiperiod supply forecasts. While the characteristics of specific applicants in the future will be unknown, their aggregate characteristics can be estimated from short-term trends, Army policies and missions, demographic projections, and economic forecasts. (See, for example, Dale and Gilroy 1983.)

The next section describes an overview of EPAS and how it will address all of the above problems.

The EPAS Design

EPAS is under development to solve the variety of problems described above. EPAS encompasses a series of integrated modules that perform forecasting, optimization, and decision analysis for personnel allocation. The system is entirely resident on its own microcomputer.

EPAS performs two functions. First, it will support Army guidance couselors by recommending specific training assignments to applicants when they sign their enlistment contracts. Secondly, it will support Army personnel planners as an analysis tool to evaluate the impact of personnel and recruiting policies.

EPAS comprises four main modules. These are:

- The Training Requirements Module
- The Manpower Availability Module
- The Horizon Planning Module (HPM)
- The Sequential Classification Module (SCM)

Figure 2 describes the relationship of these modules to one another and their system environment. An overview of each of the modules is provided below.

The Training Requirements Module

The Requirements Module provides EPAS with the schedule of training classes and the aggregate MOS training goals. The information will be obtained from the Army Training Requirements and Resource System (ATRRS).

The Requirements Module primarily provides EPAS with the number of training seats to be filled over the year and the schedule of training classes. However, it is up to EPAS to determine the optimal class fill within some upper and lower bounds (see the discussion on the HPM). Also, when EPAS is operated in the policy analysis mode, the desirability of alternative training schedules can be evaluated using the criteria resident in EPAS (e.g., difficulty of fill, performance, cost).

The Availability Module

The Availability Module will provide EPAS with forecasts of the number and types of people who are likely to be available to the Army

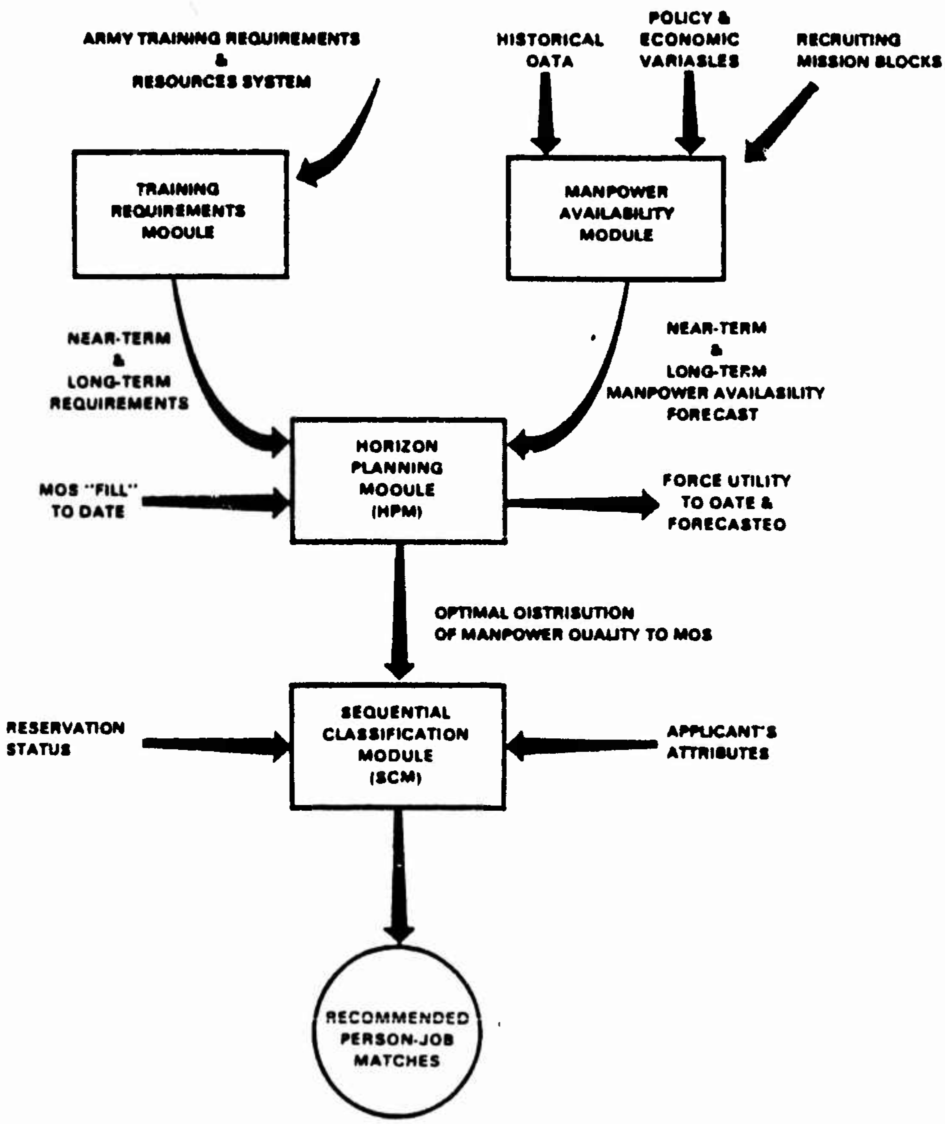

Figure 2. Enlisted Personnel Allocation System

over the planning horizon. It uses information from the Armed Forces Qualification Test (AFQT). The AFQT is a subtest of the ASVAB and is currently used to establish applicants' eligibility for enlistment and for special incentives. Essentially, it measures general intelligence. The Army defines AFQT category groups as follows:

AFQT Category	Percentile of Reference Population
I	93-100
II	65-92
IIIA	50-64
IIIB	31-49
IV	10-30
V	1-9

AFQT Category V applicants are prevented by law from enlisting. Note that AFQT Categories I-IIIA represent the upper half, in trainability, of the general population. The Army refers to AFQT Categories I-IIIA as "quality applicants."

AFQT categories are insufficient for EPAS forecasts. Rather, the EPAS Availability Module disaggregates forecasts of Army applicants into supply groups with a level of detail appropriate for estimating performance in various MOS. These supply groups are based on combinations of special aptitude tests in the ASVAB that can predict potential performance in groups of MOS. Using this information, applicants with a high aptitude for all MOS would likely be allocated differently than applicants with a high aptitude in electronics, but with average aptitude for other MOS.

The contract availability forecasts for EPAS reflect Army recruiting missions, short-term trends, and selected policy variables. USAREC recruiting missions, in use as goals since FY81, have been the major factor in determining the numbers and types of Army contracts (Moore et al. 1983). Short-term trends will also be accounted for in

EPAS. Sustained trends can also provide an early indication of significant changes in the recruiting environment. The Availability Module will also account for such controllable factors as bonuses, military compensation, number of recruiters assigned, and environmental factors such as youth population, unemployment, and civilian wages.

Finally, the EPAS Availability Module gives Army analysts a personnel policy simulation capability. It can support "what if" exercises, such as evaluating the impact of bonus policies on the number and types of applicants.

The Horizon Planning Module

The HPM computes an optimal allocation strategy for assigning supply group categories to MOS over the length of the DEP. It uses a large-scale network optimization approach to develop an ordered list of MOS training assignments for each supply group and each time period. The HPM also provides information on selected management alternatives and measures of their value in different recruiting environments.

Several important research questions have been addressed in the development of the HPM. These include optimization methodologies, definition of decision variables and problem dimensions, estimating key parameters for making tradeoffs, and the transfer of information to the operational decision modules.

For example, one problem was defining the decision problem which the HPM should model. Components of the problem include predicted MOS performance, training costs, attrition, reenlistment potential, and maintaining a high probability of meeting requirements. These components influenced the size and structure of the optimization problem and the solution methodology. Also, the way Army goal achievements are measured determines the precision required for parameters. A network optimization formulation was selected; Section II discusses the design in detail.

The HPM has excellent potential for assessing alternative recruiting policies. It could, for example, examine the impact of changing recruiting mission goals, alternative delayed entry policies, modified MOS class schedules, or changes in the supply of applicants. Furthermore, policies could be evaluated using meaningful operational measures, such as project MOS performance, attrition, retention, cost, or training class fill.

The Sequential Classification Module

The SCM provides Army guidance counselors with ordered lists of MOS recommendations for each prospective enlistee. In contrast to the HPM, which deals in aggregate supply groups or personnel categories, the SCM operates at the individual applicant level.

The current Army person-job match system also uses sequential classification. It computes ordered lists of MOS training assignments primarily on filling near-term openings in high priority MOS. Although our design for the SCM has improved measures of applicant specific performance in an MOS, its key feature is the incorporation of the ordered lists of recommended MOS assignments (for each supply group) provided by the HPM. This approach overcomes the myopic limitations of sequential classification by incorporating information from the HPM optimal solution.

By using the "look ahead" perspective from the HPM, the SCM can account for conditions such as supply and demand fluctuations. For example, if the combination of forecasted recruit availability and MOS requirements so warrant, the SCM will discourage minimally qualified applicants from certain MOS, thus reserving training seats for expected high aptitude people.

This analogy may be helpful in understanding the HPM and SCM: the HPM is like an investment outlook that includes short- and long-term recommendations for buying and selling stocks. The SCM is like the account executive who interprets the forecast in light of investment goals of a specific client.

In much the same way, the HPM will recommend aggregated (by supply groups) recruiting strategies to the SCM through presentation of an ordered list of assignments. The SCM modifies this information with the specific experiences, capabilities, and applicant preferences to recommend the most beneficial MOS classifications. Additional information on the SCM methodology is in Section II.

Benefits And Results To Date

The development of the EPAS is a long-term effort involving the commitment of substantial Government and contracting resources. In order to justify these costs, EPAS will need to demonstrate substantive improvements in the personnel allocation process. The following EPAS benefits are expected:

- Improved soldier performance
- Improved recruiting efficiency
- New policy analysis capabilities

Improved Soldier Performance

Improved soldier performance will result from a better match between a recruit's capabilities and the job's requirements. By using the EPAS methodology to assign recruits to an MOS, it is possible to substantially improve the recruits' probability of job success as well as their likelihood of completing their term of service.

The following are estimates of the value of the improvements generated by EPAS in personnel allocation:

- Job skill improvements that would cost $97 million to achieve with current recruiting policies (Schmitz and Nelson 1984).
- Retention gains that would reduce training costs by $14 million (Nelson and Schmitz 1984).

- Reductions in computer time sharing costs saving $10 million.

Improved Recruiting Efficiency

Recruiting efficiency can also be improved. Research found that nearly half of the high-quality Army applicants do not sign contracts (Schmitz and Nelson 1984). EPAS would likely improve the probability these applicants would sign because it can reserve the more desirable and challenging MOS for them.

New Policy Analysis Capability

EPAS will provide decision makers in the Office of the Deputy Chief of Staff for Personnel (ODCSPER), US Army Recruiting Command (USAREC), and the Military Personnel Center (MILPERCEN) with new policy analysis capabilities. Recruiting goals, economic effects, compensation and bonuses, and other factors can be pretested by using EPAS. The complex interactions of various personnel policies can be simulated prior to implementation. Furthermore, EPAS will be able to translate the impact of possible actions into meaningful cost and performance measures.

EPAS Status

Work began on EPAS in October 1982. The full system will be ready for operational testing in April of 1985. The following sections describe the design of the prototype, which is the same as the operational system, except for the level of detail. We also discuss the ADP implementations of the Prototype EPAS and present results from example EPAS runs.

II. MANAGEMENT SCIENCE APPLICATIONS

Overview Of Management Science Applications

This project incorporates an exciting mix of management science techniques. The following are some management science applications in our development of a system for optimum person-job matches for Army applicants:

- Systems Analysis
- Forecasting
- Linear Optimization
- Quantifying Human Judgment
- Simulation
- Policy Analysis

After the following overview of how each of these techniques is used in EPAS, specifics on each application are presented.

Systems Analysis

Determining user requirements and the environment within which a system must operate is crucial to successful implementation of a complex decision support system. For this reason a comprehensive analysis of the systems supporting Army recruiting was conducted (McWhite et al. 1983).

Forecasting

One of the greatest challenges of this development is forecasting the number and type (or quality) of applicants who would sign Army contracts in a given time period. Using a time series of Army applicants, we have developed such a model which provides forecasts for the next fiscal year. Our model was developed using linear regression and an auto-regressive trend formulation.

Linear Optimization

Key to the success of EPAS is the capability to "look ahead" and recommend the type of applicant who should be assigned to a given time-phased Army skill training class opening. In general, when applicant quality is high, many technical MOS can be filled with these people. However when quality is severely constrained, the optimization must reflect the Army's priorities for assignment of these people. In fact, Army accession quality is seasonal, and the DEP is used to smooth applicant flow. The EPAS optimization recommends the DEP lengths (the time between signing a contract and starting training) for applicants arriving at different times which will smooth applicant flow while apportioning the scarce resource of high quality applicants in accordance with Army priorities.

Quantifying Human Judgment

The SCM examines the various factors involved in making the person-job match and relates them based on a quantification of "judgments" such as would be made by a human making a similar decision. Specific techniques that we are either using or investigating are:

- Policy Specification (Ward et al. 1979), which identifies a functional relationship between two interacting independent variables.
- Utility Theory (Stillwell 1983) to identify models of judgment specific to the Army's requirements.
- Artificial Intelligence techniques such as expert systems (Unger 1983) to examine as a means of capturing "decision rules" used by expert guidance counselors.
- A heuristic approach to define and simulate decision criteria.

Simulation

The Process Test System (PTS), described in Section III, represents the primary application of simulation in EPAS. It serves two functions:

- **A test framework for development.** Modifications to modules can be evaluated in the context of the entire system.
- **Policy analyses.** Users can simulate EPAS behavior under different scenarios of applicant supply, requirements, and Army policy.

Policy Analysis

The EPAS simulation capability has been designed to facilitate policy analysis of important Army personnel management problems. An early effort (Nelson and Schmitz 1984) compared EPAS to the current MOS allocation process. This work defined a Pareto-optimal efficiency frontier that showed that improvements were possible in both the objectives of improving job performance and reducing attrition.

A recent EPAS allocation analysis demonstrated that aggregate performance increases were possible without lowering the quality (AFQT category) of assignments to many MOS.

These and other analyses are discussed later in this section. They suggest that the value of EPAS can be many times its $2 million amortized development and operation cost.

Systems Analysis

We assert that many complex decision support systems fail on implementation because of an inadequate specification of the environment in which they must operate. For this reason a comprehensive systems analysis of current Army manpower systems and processes was a key component in EPAS development.

Systems Analysis Scope

The EPAS Systems Analysis (McWhite et al. 1983) provides a description of the systems and processes which support the Army's accessioning process. It describes the operating environment in which

systems and processes interact to identify training requirements; and the activities, systems and procedures involved in recruiting, selecting, classifying, and enlisting qualified applicants in the quantity and quality required by MOS.

EPAS will be a component of the Army's Manning System, which integrates the policies, procedures, and management tools required to define and man the Army with qualified soldiers. The Manning System life cycle phases are:

- Structure
- Acquire
- Train
- Distribute
- Deploy
- Sustain
- Develop
- Separate

The Systems Analysis encompasses the Acquire and Train phases, focusing on the systems and processes that support the selection, classification, and initial entry training (IET) of enlisted personnel. For this analysis, these systems and processes are combined in the Accession/IET Process. Both current and planned systems are discussed.

Systems Analysis Findings

The Systems Analysis revealed redundant data input to the various data systems used in the accessioning process as documented in McWhite et al. (1983). This redundancy is costly, time consuming, and generates errors in critical personnel data. For example, numerous systems in the accessioning process are dedicated to specific functions. These dedicated systems do not, for the most part, communicate with other functional systems in the accessioning and training environment.

The Systems Analysis points to a need to improve the allocation of personnel quality. Current methods do not approach an optimal person-job match. Rather, they rely on matching an applicant to a job

based on only minimum qualification standards for an MOS. Emphasis is on meeting near-term MOS training seat openings for high priority MOS. This emphasis is on quantity at the expense of quality. Current person-job match techniques also lack capabilities for determining recruit-unique skills and matching them with MOS in which the recruit could be best used and have a high probability of performing successfully.

Systems Analysis Methodology

The sequence of tasks followed in the Systems Analysis were:

- Gather information.
- Describe personnel systems, processes, actions, and policies by functions and interfaces.
- Determine the operating environment of the personnel systems.
- Determine the EPAS role within the recruiting/reenlistment system.
- Prepare systems analysis documentation.
- Review task progress results.

Information was obtained from applicant and group interviews plus reviews of pertinent literature and references. Fact sheets were prepared which describe the Accession/IET Process systems, programs, and processes. Division chiefs, office heads, branch chiefs, and action officers were interviewed. Army directives and circulars, plus Army Training and Doctrine Command (TRADOC), USAREC, and MILPERCEN publications were reviewed. The interviews and literature search focused on:

- Identification of specific functions within the Requirements and Accession/IET Processes.
- Identification of directives.
- Identification of the interfaces among the functions, systems, and processes of the Requirements and Accession/IET Processes.

Logical Organization of the Systems Analysis

The systems and processes described in the Systems Analysis are categorized in three groups:

- Enlisted Training Requirements Determination - The Army uses a combination of budget data, manpower requirements data, and comparisons of training requirements to resources to determine enlisted training requirements.
- Acquire (Accession) Phase - Accessioning is the process of obtaining qualified and motivated volunteers to meet manpower requirements. The process is comprised of four stages: recruiting, qualification, classification, and enlistment.
- Training Phase - Training, within the scope of this analysis, refers to entry level training. In addition to introducing enlisted members to basic Army skills, this phase provides instruction in the job that will be the applicant's first assignment.

There is interdependency among these groups. Determination of training requirements depends in part on the establishment of force structure and the ensuing authorizations. The force structure and authorizations processes as well as many others affect EPAS but are beyond the scope of the Systems Analysis. The definition of training requirements is germane to EPAS and is therefore addressed in the Systems Analysis.

The Systems Analysis identifies the environment in which EPAS must function and, therefore, is an important precursor to the EPAS Functional Description. The Systems Analysis forms the foundation from which the Functional Description will delineate the specific capabilities that EPAS must have to support Army goals of obtaining quality as well as quantity in the increasingly competitive manpower marketplace.

Forecasting

EPAS requires forecasts of the number and types of applicants who will accept Army enlistment contracts over the planning horizon. These forecasts must incorporate more information than a distribution of applicant AFQT scores or categories. Rather, the forecasts must incorporate a level of detail sufficient to provide predictors of applicants' differential performance in the MOS that accept recruit accessions.

Problem Statement

The objectives of forecasting the supply of applicants, which the Availability Module will generate in support of EPAS, are twofold:

- Develop forecasts for a one to two year period to provide EPAS with a "look ahead" capability to match future supplies with projected Army requirements.
- Provide forecasts of the available supply at a level of detail and accuracy sufficient to permit differential classification of recruits to MOS.

The level of detail required will be established through the methodologies described below. At a minimum, supply groups need to be stratified by the quality of the personnel mandated by Congress and by measures of ability to perform particular jobs in the Army. These measures will allow EPAS to differentiate among applicants of similar quality in the MOS allocation process.

Procedure for Current Methodology

The Army states its requirements for recruits as "missions" categorized by:

- gender
- education level
- AFQT category

In addition to these goals, various limits and goals are set on the quality of enlistees by Congress, the Department of Defense, and the Army. For example, Congressional limits are set on the number of applicants who are permitted in AFQT Category IV. Conversely, quality goals are set for the Army on the number of applicants permitted in Categories I-IIIA.

USAREC apportions monthly recruiting missions to the 56 Recruiting Battalions for contracts. Contracts are defined as the point at which an applicant accepts an enlistment contract, takes the oath of military service, and has an MOS training seat reserved. EPAS is primarily concerned with enlistment contracts since the applicant's MOS is determined at this point.

An Applicant Categorization Which Supports EPAS

Reliable forecasts of applicants by demographic categories are necessary but not sufficient to support the EPAS. Mission goals and AFQT category in particular, do not give any estimate of the differential utility of assigning applicants to different MOS. EPAS needs to recognize differential ability of applicants, i.e., what they do well versus what they cannot do well, in order to make tradeoffs between supply groups.

The estimation of an applicant's job performance will need to include the aptitude area composite scores which the Army defines from the ASVAB subtests. Table 1 gives the ASVAB aptitude area composites and the major jobs associated with each composite. Aptitude area scores are not only important for their intrinsic predicting value in post-training performance, but also because many jobs have minimum standards for qualifications stated in terms of these composites.

If we arbitrarily define a highly qualified applicant as one who scores above a given standard (e.g. 110) on the ASVAB composite for a group of MOS, then the optimal HPM solution will tend to allocate groups with applicants who are highly-qualified in a single group of

TABLE 1

COMPOSITION OF APTITUDE AREAS

Aptitude Areas	Major Jobs in Each Aptitude Area
CO (Combat)	Infantry, Armor, Combat Engineer
FA (Field Artillery)	Field Cannon and Rocket Artillery
EL (Electronics Repair)	Missiles Repair, Air Defense Repair, Electronic Repair, Fixed Plant Communications Repair
OF (Operators and Food)	Missiles Crewmen, Air Defense Crewmen, Driver, Food Services
SC (Surveillance and Communications)	Target Acquisition and Combat Surveillance, Communication Operations
MM (Mechanical Maintenance)	Mechanical and Aircraft Maintenance, Rails
GM (General Maintenance)	Construction and Utilities, Chemical, Marine, Petroleum
CL (Clerical)	Administrative, Finance, Supply
ST (Skilled Technical)	Medical, Military Policeman, Intelligence, Data Processing, Air Control, Topography and Printing, Information and Audio Visual

MOS to those jobs and then fill in the gaps with applicants who are highly qualified in more than one area. This a priori structure for the optimal solution assumes that the largest costs of misallocation will occur when an applicant is allocated outside of an aptitude area for which he is highly qualified. If assignments were random, such misallocations would occur most often for applicants highly qualified in a single area since they have more categories in which to be misallocated than applicants who are highly qualified in more than one aptitude area. This suggests defining EPAS supply groups as combinations of applicants, within each mission box, who score above or below 110 on each combination of aptitude composites and aggregating until reasonable cell sizes are achieved.

Moore et al. (1983a) show that USAREC's mission goals can serve as the forecast of the enlistment contracts for each recruiting mission box category. They further show that the distribution of aptitude area scores is relatively constant across time, once mission boxes are accounted for. Moore et al. (1983b) developed historical factors from fiscal year 1982 contracts based on the distribution of aptitude area scores. They provided rationale for applying these factors to mission goals to generate forecasts of contracts by supply groups.

Forecasting Supply Groups

The most desirable recruit category for the Army is the male, high school graduates in AFQT Categories I-IIIA. Nearly 50% of all contracts are in this mission area. Moore et al. (1983b) show that partitioning this group into the first two quartiles of AFQT category scores provides good differentiability because applicants in the first quartile average higher scores on many more composites and combinations of composites than do applicants in the second quartile. This partitioning allows for more allocation flexibility by the HPM by permitting a distinction between adequate performers and very good performers in each MOS.

The Availability Module considers three methods for forecasting the number of contracts of male, high school graduates and seniors in the two quartiles of mental categories I-IIIA. In each case the previously discussed factors are used to break down the more aggregate forecasts into supply groups. These methods are:

- Recruiting Command's mission goals
- Monthly econometric model
- Autoregressive-trend model

USAREC Mission Goals

The most basic forecasting method is to simply take the USAREC monthly goals by mission box. This method would have been an excellent predictor during FY81-83. Furthermore, it is a useful forecast for planning purposes. For example, EPAS can provide feedback to USAREC, ODCSPER, and TRADOC on the impact of allocation plans.

Econometric Model

The Econometric Model, developed by Dale and Gilroy (1983) and Horne (1984) incorporates:

- unemployment rates for males age 16-21
- male population age 16-21
- regular military compensation
- weekly production wages
- enlistment bonuses
- number of recruiters
- consumer price index

These exogenous variables are all highly correlated. In order to adjust for this, and avoid multicollinearity problems in the regression analysis, the technique of principal components is used to create a new set of exogenous variables from linear combinations of the original variables. These new variables have the property of being mutually uncorrelated.

A linear regression is performed to generate estimates for the coefficients of the new variables using the monthly ratio of the number of contracts to the male population in the 16-21 age bracket as the dependent variable. It is an algebraic exercise to compute the coefficients of the original variables. Additionally, the forecast errors are assumed to have a first order autocorrelation and this autoregressive parameter is also estimated.

This formulation of the model has the advantage of providing a policy analysis tool in terms of the coefficients or elasticities of the exogenous variables. Different economic scenarios, such as increased unemployment or inflation, can be evaluated for the effects on recruiting high quality applicants.

Autoregressive-Trend Model

The autoregressive-trend model performs a linear trend fit on the seasonally adjusted time series of contracts without regard to any exogenous variables. The resultant residuals or "forecast errors" are then modeled with autoregressive or lag parameters to arrive at the final form of the forecast model. This model allows an easy update of its forecasted values as actual enlistment contracts are made through the Sequential Classification Module.

Network Optimization

This section provides a detailed overview of the Horizon Planning Module of EPAS. It begins with a short discussion of the purposes of the HPM — both as a component of EPAS and as a tool separately for policy analysis. This discussion is followed by a description of how the various aspects of the recruitment and job-assignment process can be modeled by the HPM. We then briefly review the considerations that led to the selection of a pure network as the most suitable modeling methodology before proceeding to a detailed description of the specification of the network itself. A short discussion of the post-optimality analysis needed to generate

usable input for the Sequential Classification Module follows the network description. Finally, we note several refinements that will be incorporated into the operational HPM currently being developed.

Purposes

The Army's current system for assigning applicants to jobs, like those of the other Services, is sequential — as a result, it tends to respond most effectively to the immediate demands for enough minimally qualified accessions to fill available MOS training seats. The limitations of this approach create problems for the Army because the Army's applicant pool is less homogeneous with respect to basic aptitudes and the range of skill requirements is broader than in the other Services. These facts, combined with a sequential approach to personnel allocation, frequently result in serious under-utilization of the available talent pool.

To address this problem, EPAS will include a long-run planning capability as well as a sequential classification component to make the actual assignments of people to jobs. This long-run planning capability will be provided by the HPM, the design of which is the focus of this section.

The main purpose of the HPM is to provide the ability to "look ahead" to a one year horizon, recognize the predictable cyclic variations in the quantity and quality of applicant flows, and bring this information to bear on the evaluation of a given applicant for a given job. This extension of the temporal perspective from which recommendations for person-job matches emerge provides a way to avoid the "crisis management" mode of allocation that may otherwise be induced by temporary fluctuations in applicant supplies.

The HPM will accomplish this by using the supplies, demands and class sizes generated by the availability and requirements modules of EPAS to produce, for each supply group in a given period, an ordered list of the "best" MOS assignments for that supply group. This list

is accepted by the SCM, and modified by applicant-specific characteristics of the applicants.

A second purpose of the HPM is to provide Army decision-makers with a policy analysis tool. For example, the HPM can be used to assess the effects of "management levers" such as DEP policy, quality distribution goals, recruiter incentives, and bonus programs. It will permit exploration into the consequences of demographic and economic trends, and the impact of changes in personnel requirements resulting from the introduction of new technologies.

These policy analysis uses of the HPM have been taken into account in the design process by insuring that flexibility to define problems and select output reports is provided. However, the primary emphasis in the development of the prototype has been to provide guidance, through the SCM, that will enable the Army to exercise both frugality and foresight in its immediate allocation of human resources.

Problem Definition

The skeleton of the problem to be solved by the HPM is to allocate a set of supplies, available at specified times, to meet a set of time-specific demands in such a way that the value to the Army of the resulting distribution of manpower to jobs is maximized. The supplies are the forecasted numbers of applicants signing contracts in each period. The demands are the numbers of class seats available in each time period for each MOS. The value to the Army of a given person-job match is a function of (a) the expected job performance resulting from the match; (b) the relative value or "utility" to the Army of that level of performance; and (c) the length of time the person can be expected to remain in the job.

If the problem were completely described by this "skeleton," the solution would be relatively straightforward. However, to accurately model the recruiting environment, the HPM must accommodate a number of additional goals, objectives and constraints.

Annual Demands

The first goal of the system is to insure that sufficient numbers of qualified people are trained in each MOS to meet the annual requirement. Obviously, if the sum of available training seats over the year were exactly equal to these demands, this requirement would be redundant. This is not, however, the case.

Class Size Bounds

AIT classes provide training for Army Reserve and National Guard personnel as well as for regular Army enlistees. As a result, the proportion of seats in a given school filled by regular Army enlistees may vary, within limits, from one school session to another. Thus the sizes of the classes filled by the HPM may vary with time, but the total cohort trained each year must satisfy the annual demands in each MOS.

Delayed Entry Program

The primary tool available for smoothing out cyclic variations in applicants is the DEP, which allows applicants to delay their reporting date for up to one year after signing a contract. There are both costs and benefits, as well as policy constraints associated with use of the DEP that must be incorporated into the HPM.

The maximum length of the DEP is established by Army policies, and may vary with the characteristics of the applicant. Only high school seniors in Categories I-IIIA are allowed to delay entry for as much as one year, for example.

Because recruits hold Army Reserve status from the time of signing a contract until they begin active duty, there is a cost (in increased active duty pay and earlier retirement eligibility) that increases with the length of the delay period. On the other hand, studies have shown that some delay between signing a contract and actual accession tends to reduce the propensity for attrition, especially among applicants in the lower AFQT categories.

Minimum Qualifications

In order to be eligible for assignment to a given MOS, an applicant must achieve a minimum score on one or more composites of the ASVAB. While these standards will be enforced by the SCM, the HPM must take them into account.

Gender Restrictions

MOS in combat arms are closed to women. This imposes requirements that (a) males and females are not aggregated into the same supply groups; and (b) female supply groups may not be allocated to the restricted MOS.

Quality Distribution Goals

A procedure that sought only to maximize job performance and longevity payoffs could tend to assign highly qualified applicants exclusively to those MOS requiring high levels of aptitude. If such a strategy were followed, the result would be a serious leadership void in the career force of MOS with less demanding initial requirements. In recognition of this tendency, the Army establishes "quality distribution goals" that specify minimum percentages of accessions from the upper AFQT categories for MOS. These goals must be recognized by the HPM.

Prerequisites

Some AIT courses require completion of another course prior to entry. For example, entry into MOS 91D (operating room specialist) must be preceded by completion of training for MOS 91B (medical specialist). Thus a proportion of the applicants assigned to AIT for 91B must fill the annual demand for accessions in that MOS, while other assignments to that course will fill subsequent classes in 91D and eventually flow into the annual pool of "new hires" in 91D. This pattern must be reflected in the class size bounds.

Priority

To deal with the possibility that supplies of new enlistees are insufficient to meet requirements in all MOS, the Army has established priorities for filling different MOS. In general, MOS in the combat arms have top priority, followed by intelligence MOS, with clerical specialties lowest on the list. In general, the higher priority MOS are the more difficult to fill. Therefore, the HPM must incorporate these priorities to ensure that there are enough SCM presentations to ensure fill of high priority openings.

DEP and Training Losses

Not all contracts become accessions. Losses from the DEP occur and are desirable to a certain extent because these losses could otherwise occur as attrition during or after training, with correspondingly larger costs to the Army. These losses are not so large that they must be modeled to obtain the level of accuracy required in the HPM solution, but it may be desirable to model them for policy analysis purposes.

A certain percentage of matriculants to AIT courses fail to complete training, requiring either a repeat cycle through the same course, or transfer to a different school. These events are costly to the Army, and it is clearly desirable to minimize their frequency. To a great extent, this minimization can be achieved by simply maximizing both expected job performance and longevity. For some purposes, however, it might be useful to treat the minimization of training losses and recycles as a separate objective.

Table 2 provides a summary of the components of the problem just described. It should be noted that the designation of problem components to the roles of "objectives" and "constraints" in this summary is not inherent in the structure of the problem. Some components, such as quality distribution goals, may be treated either as objectives or as constraints (or, as will be seen later, both).

TABLE 2

SUMMARY OF PROBLEM STRUCTURE

Objectives

Maximize:	Performance
	Longevity
	(Value of Performance)*
Minimize:	DEP Costs
	(DEP Losses)
	(Training Losses and Recycles)

Constraints

Applicant Availability
Class Size Bounds
Annual Requirements
Quality Distribution Goals
Eligibility Standards
DEP Policies
Sex Restrictions
(Priority)
(Prerequisite Courses)

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*Items in parentheses are not included in the prototype HPM.

The prototype HPM does not directly incorporate all of the elements described above. Rather it focuses only on the critical components of the recruitment process. One of the purposes of the prototype EPAS is to explore the extent to which objectives and constraints omitted from this formulation are likely to affect the recommendations generated by the system, and to evaluate the costs and benefits of incorporating these features in the operational model. The problem elements not included in the prototype HPM are enclosed in parentheses in Table 2.

Methodology Selection

There are a variety of techniques available for solving optimization problems of the kind described above. These include linear and goal programming, multi-objective programming, and pure and generalized networks. The selection of a particular technique for a specific problem is a multi-criteria decision problem in itself, involving tradeoffs among computational complexity, solution time, precision, and the amount of abstraction required in the translation of the problem into the form required by the methodology. Typically, the more precise and less abstract the specification, the more computationally complex the problem becomes. On the other hand, the extensive use of abstraction in pursuit of a more parsimonious representation of the problem often leads to a mechanism that is impossible for the user to understand and to a solution that may ignore or obscure critical aspects of the problem. Another important consideration is the availability of solution algorithms with the capability of solving the problem efficiently.

Evaluation of these tradeoffs has led to the selection of a pure network approach for the HPM. The extremely efficient solution algorithms that have been developed for these types of problems make the solution of very large problems feasible. The size of the problem to be solved by the HPM is a function of the precision with which we differentiate among aptitude groups, job classifications, and time periods. The pure network approach allows for a specification that

captures the essential distinctions among applicant characteristics and job requirements without exceeding the practical bounds on problem size and solution time.

It should be noted that the use of a pure network imposes some limitations. Some aspects of the recruitment process, such as losses from the DEP and training would, if they were to be explicitly incorporated into the HPM, transform the model into a generalized network. Other potential goals and objectives, such as targets on proportional distributions by gender or race would transform the problem to an embedded network linear program and force either a drastic reduction in the level of detail or an explosion in the solution time. However, the main function of the HPM is to provide a set of "approximately optimal" solutions for use in the SCM, rather than a single precisely optimal allocation. This fact mitigates in favor of a more detailed specification producing a slightly less precise solution—i.e., in favor of a pure network approach, at least for the operational version, where "reasonable" solution time is an important consideration.

Network Structure

Figure 3 depicts the network used for the prototype version of the HPM. As can be seen from the figure, this is a layered network. (If we define the network in the conventional way as a graph G=(V,E), where V is the node-set and E is the set of admissible arcs, then V can be partitioned into subsets {V1,V2, — Vm} such that V1 U V2 U — U Vm = V, and Vi Vj = 0 for all (i,j), and if node v(i) is an element of Vi and node v(j) is an element of Vj, then an arc for v(i) to v(j) is an element of E if and only if i<j.) The layers are distinguished by heavy lines, and numbered from I to V.

As noted above, problem size is a limiting factor for the HPM. The objective of implementing EPAS on a microcomputer, combined with the use of the ARCNET code (which is very fast but also quite demanding with respect to computer memory requirements) makes this

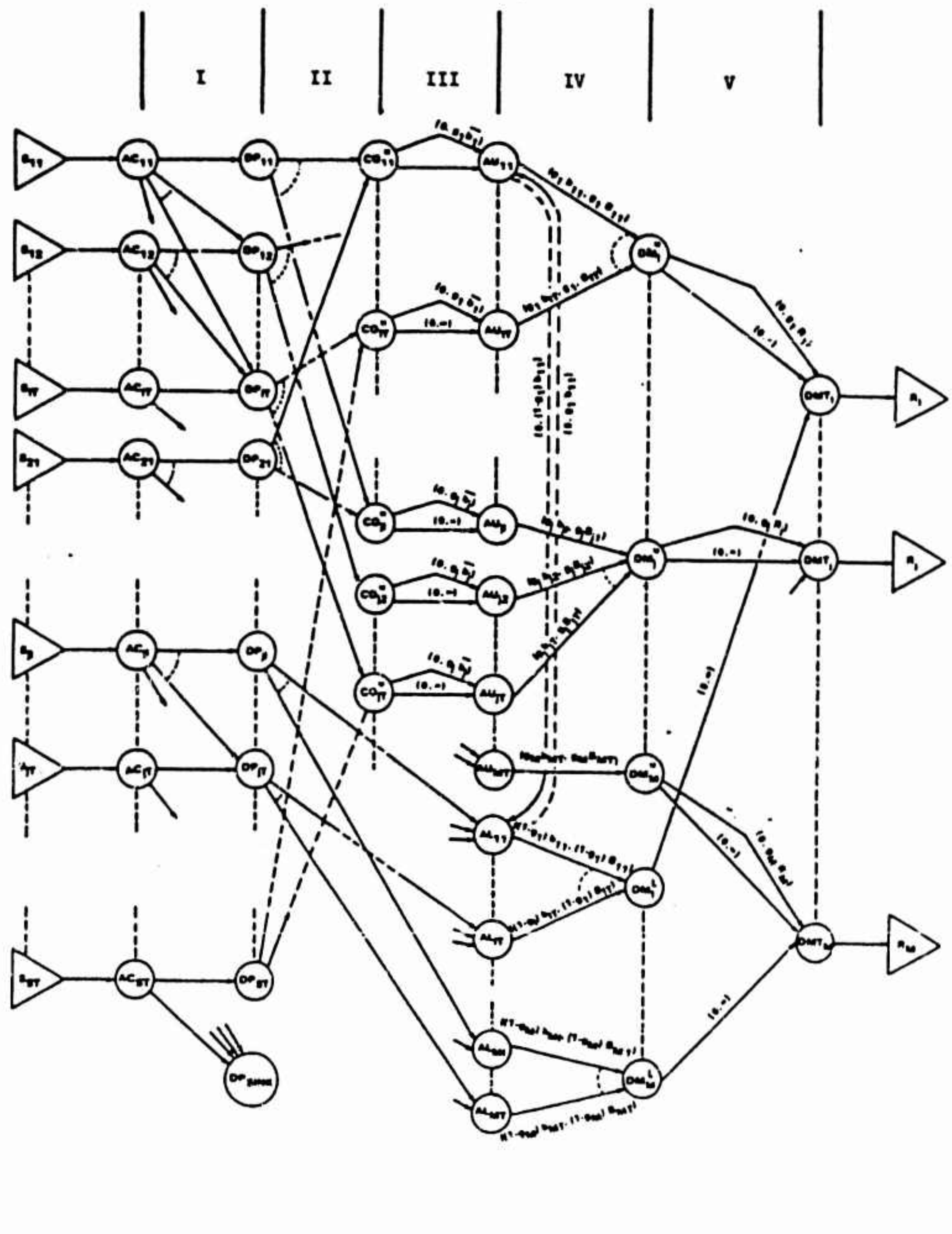

Figure 3. HPM Prototype Formulation

factor particularly crucial. (ARCNET is a primal simplex pure network solution code developed by Analysis, Research and Computation of Austin, Texas.) Thus, the network design in Figure 3 models the accession process as if it were more incremental than it actually is — that is, by modeling the assignment of an applicant to a particular AIT course as if it occurred in two stages — first, the assignment to an accession date (or DEP length), and then to a specific MOS. The result is a network with a slightly larger node-set than would be required if the actual assignment decisions were modeled explicitly, but with an arc-set that is roughly one fifth as large. An in-core/out-of-core version of ARCNET is being developed for the HPM (Klingman 1984). This will vastly expand maximum problem size, thus allowing for specification of a "single stage" model. This and other refinements to the model are briefly discussed at the end of this section.

The processes modeled at each stage of the network are as follows:

Level I

Node AC(i,t) represents the available supply of applicants in AFQT Category i at time t. Supply groups 1 through (j-1) are designated "high quality" groups, and are eligible to satisfy quality distribution goals. Applicants flow from each AC node into a DP(i,t+k) node that represents the applicants in category i available for assignment to an AIT classing period t+k, or into a DEP "sink" representing the assignment of an applicant to a time period beyond the HPM horizon. An arc [AC(i,t),DP(i,t+k)] exists if and only if $k \geq 0$ and $k \leq P(i)$, where P(i) is the maximum allowable DEP length for applicants in category i.

The costs on arcs in Level I reflect the Army's preferences for the length of the DEP. That is, the unit cost DC(i,k) on flows from AC(i,t) to DP(i,t+k) increase linearly with the value of k, for $k > 1$, reflecting the increases in pay due to time in the DEP. The slope of

the DEP cost function, C(i,k) is larger for low quality than for high quality aptitude groups, reflecting the desire to maximize flexibility in the assignment of high quality applicants. For values of $k \leq 1$, a "penalty cost" is imposed to reflect the increase in expect expected attrition rates resulting from very short delay periods.

Finally, costs on flows into the DEP sink are zero for all supply groups. The tendency for this to encourage the "dumping" of low quality supply groups into future periods and avoid the high costs associated with these groups is counteracted by constraints at Level IV of the network which enforce a balance among flows beyond the horizon.

This formulation does not provide for the explicit modeling of applicants who take the DEP beyond the HPM horizon. This feature could be easily accommodated through the use of multiple DEP sinks, with a minimal increase in network size. Since the operational version of the HPM will, on a given run, be concerned only with finding the optimal allocation for aptitude groups in the near future, such precision is unnecessary. However, for policy analysis purposes, it may be desirable to simulate the operation of the system over several years, with successive runs of the HPM, each using the results of the previous run as a starting point. For such an application, the more explicit approach would be used.

Level II

A unit of flow from DP(i,t) to CO(m,t) represents the allocation of an applicant from supply group i who has been assigned an accession date in period t to an AIT course in MOS m with a starting date also in period t. The function of the CO nodes is to act as "collectors" for all "high quality" assignments to a given AIT class. This permits the satisfaction of quality distribution goals by drawing on the entire set of high-quality flows. Without these collectors, it would be necessary to impose quality distribution goals on each high-quality group, resulting in a severely over-constrained specification.

Since the collectors are needed only to aggregate high group quality assignments, arcs from nodes for "low quality" supply groups pass through Level II to the AL nodes in Level III. However, since these flows represent the same assignment of supply group to AIT class represented by the DP-CO arcs, they carry similar costs and are constructed according to the same rules as are the Level II arcs. An arc from DP(i,t) to CO(m,s) or to AL(m,s) exists if and only if:

- s=t
- Either MOS "m" is open to both men and women or aptitude group "i" is male.

The costs on arcs from DP nodes to either CO or AL nodes reflect the "payoffs" for the person-job match. In the current formulation, these costs are a function only of expected performance and longevity. One of the primary purposes of the prototype model is to determine the sensitivity of results to the kinds of variation in payoffs that would result if "utility of performance" were added to this function. If experimentation demonstrates that results are sensitive to such variations, additional research will be undertaken to develop appropriate measures and incorporate them into the model specification.

Expected performance is measured by predicted scores on Skill Qualification Tests (SQT), which are calculated as a function of aptitude scores for each MOS (See Schmitz and Nelson 1984). Predicted SQT is calculated for each supply group-MOS combination by using the mean score for the relevant supply group.

Expected longevity is also a function of education level, aptitude scores, and MOS assignment. The measure used for this term is "expected term of service" (ET), as calculated by Baldwin (1983). Because the problem is specified as a minimization, the values of predicted SQT and ET are inverted to yield a "less is better" ranking. As noted earlier, eligibility for an MOS requires a minimum score on one or more aptitude composites. This prohibition is not directly

incorporated within the HPM, but scores low enough to result in ineligibility will produce very large performance/longevity costs, and thus strongly discourage "illegal" allocations in the optimal solution. The final check to insure against such assignments will be carried out by the SCM.

Since a primary objective of the HPM is to find an allocation that will maximize performance/longevity payoffs through the DEP, these payoffs will be more influential than DEP costs in guiding the HPM's search for optimality. Therefore, both predicted SQT and ET scores are scaled so as to make them preemptive with respect to DEP costs. Finally, the two terms are merged in a linear combination with user-specified weights to produce a cost that is highest for the least desirable person-job matches, and lowest for the most desirable.

Level III

The purpose of this level of the network is to encourage a stable quality mix in the various AIT classes for each MOS. This is accomplished through multiple capacitated arcs linking each pair of nodes in this level. By providing for the different costs on flows between a single pair of arcs, this approach provides a piece-wise approximation to a non-linear cost function.

The prototype HPM uses only two arcs between each pair of nodes. These arcs allow us to associate a negative cost with flows up to the quality goal for a given class, and zero costs on flows in excess of the goal. If a more flexible specification is desired, additional arcs imposing increasing costs as the gap between desired and realized flows increases will be added.

Since class sizes are allowed to fluctuate between upper and lower bounds, mean class sizes are used to generate the upper bounds on goal arcs. (Mean class size for an MOS is the annual demand for that MOS divided by the number of classes.) These mean class sizes are designated b(m,t) on Figure 3.

Quality distribution goals for each MOS are specified as a minimum percentage of annual accessions that must be drawn from the high quality AFQT categories. These goals are represented in the network diagram as g(m). Each pair of nodes CO(m,t)-AU(m,t) is thus linked by one arc with a lower bound of 0, and upper bound of g(m)b(m,t), and a negative cost; and a second arc with a lower bound of 0, an arbitrarily large upper bound, and a cost of 0. The effect of this structure is to reduce the value of the objective function for each additional unit of flow from CO(m,t) to AU(m,t) until the goaled percentage of mean class size is reached. Flows above this level have no effect on the objective function.

The size of the negative costs in this level will affect the distribution of high quality applicants to an MOS at a given time period. Given the fact that annual quality goals are more critical, these costs will always be less negative than those used on the arcs in Level V which enforce the annual targets. The size of these costs relative to performance/longevity costs can be specified to reflect user-specified tradeoffs.

Level IV

This level models the flow from time- and quality-specific AIT classes (AU and AL nodes) to annual pools for each MOS distinguished only on the basis of quality (DMU and DML nodes).

The arcs in Level V are of two types: A*(m,t)-DM*(m) arcs; and balancing pairs of AU(m,t)-AL(m,t) and AL(m,t)-AU(m,t) arcs. The A*-DM* arcs represent the flows from AIT classes to the appropriate annual pool. The A*-A* arcs exist only to avoid spurious infeasibilities that may be induced by the mechanism employed to enforce class size bounds.

For example, limits on fluctuations in class sizes are enforced by upper and lower bounds (designated B(m,t) and b(m,t) in Figure 3) on the A*-DM* arcs. Since these bounds actually apply to the sum of

both high and low quality flows, they must be adjusted to be applied separately to the two flows. This is accomplished by imposing lower bounds of g(m)b(m,t) on AU-DMU flows, and (1-g(m))b(m,t) on AL-DML flows. Similarly upper bounds of g(m)B(m,t) and (1-g(m))B(m,t) are enforced.

The effect of this set of bounds is to require at least some minimum flow of low quality accessions into the annual pool for many MOS. (The requirement is not imposed on MOS for which only high-quality groups are eligible. For these MOS, the value of g(m) is 1.) This set of constraints may, under some circumstances produce the paradoxical result of no feasible solution because of "shortage" of low-quality enlistments. A second, less paradoxical but nevertheless undesirable result can occur if there are insufficient high-quality supplies to meet the lower bounds on AU-DMU arcs. In this case the effect is that of enforcing quality bounds as if they were absolute constraints, instead of important goals.

The purpose of the AU-AL and AL-AU balancing arcs is to eliminate this inconsistency. In the case of a "shortage" of low quality supplies, the AU-AL arcs allow high quality supplies to flow through the AL nodes to satisfy the lower bounds on AL-DML arcs. In the case of a shortage of high quality applicants, low quality applicants are allowed to flow along the AL-AU arcs to meet the bounds on the AU-DMU arcs. While this creates the possibility that quality goals may appear to be satisfied when in fact they are not, such a result can be easily detected by examination of flows along the AL-AU arcs in the optimal solution.

The costs on these balance arcs are high in both directions, albeit higher when the flow is from low to high quality nodes than for the opposite case. This is done to reflect the need to achieve a balance of both low and high quality accessions over the HPM horizon, and to avoid the tendency that would otherwise exist to "dump" as many low quality supplies into the DEP sink. In essence, these costs are

intended to discourage profligate use of generally limited supplies of high quality enlistees.

Level V

The final stage in the network has two functions: (a) to insure that annual requirements for accessions in each MOS are met; and (b) to enforce (subject to the considerations noted above) the annual quality distribution goals. The annual requirements for MOS(m) are modeled as a sink with a demand R(m). The flow from DMT(m) to its sink must equal R(m). This in turn imposes the constraint that DMU(m)+DML(m) must equal the annual requirement.

Annual quality goals are imposed in a manner analogous to that used in Level III. Each pair of nodes DMU(m),DMT(m) is linked by two arcs, one with lower bound 0, upper bound "infinity", and cost 0; and another with a lower bound 0, an upper bound of the goaled proportion of annual demand, g(m)R(m), and a large negative cost. As noted earlier this cost is a larger negative value than that used in Level III, reflecting the greater importance of the annual goal.

This completes the description of the prototype network structure. The details of the implementation of this design are discussed in Section III.

Post-optimality Analysis

In order to provide the flexibility required by the SCM in making applicant MOS recommendations and to accommodate the Army policy of incorporating applicant preferences into the allocation procedure, it is for the HPM to provide the SCM with a list of recommended AIT class assignments for each supply group. To reflect the information contained in the HPM solution, this list must be ordered, and its entries "scored" to reflect, as accurately as possible, the rate at which assignments to each non-optimal alternative on the list move the HPM solution away from optimality.

It is obviously not possible to exhaust the set of feasible solutions by doing multiple runs of the HPM, which would be the only way of guaranteeing that a precise ranking of "nearly optimal" solutions could be generated. Fortunately, such a level of precision is not required. It will be sufficient for the purposes of EPAS to produce a list of thirty to fifty alternative assignments with associated scores that are suggestive of the relative value of each alternative.

This list will be generated by summing the marginal costs along each non-optimal path, consisting of combinations of each allowable AC(i,t)-DP(i,t) arc and each allowable DP(i,t)-CO(m,t) or DP(i,t)-AL(m,t) arc, depending on the supply group. The set of these sums associated with a given supply group is sorted, and the resulting values are scaled so that the alternative path with the smallest sum of marginal costs receives the highest score. Since these sums indicate the change in the objective function that would result from the transmission of one unit of flow along the relevant path, these scores are reasonable indicators of the desirability of alternative assignments for the relevant supply group. The scaling mechanism is designed into the HPM. This insures that the scores used by the SCM will not be sensitive to periodic fluctuations in the composition of the applicant pool. If it were necessary to carry out this procedure for every supply group in every period, the sorting process would be extremely time-consuming. However, at any given run of the HPM, the SCM requires the lists only for the supply groups in a single period. In the operational mode, it is expected that the HPM will always use periods beginning with the present, dropping one past period and adding one new period onto the horizon. Thus, the scoring routine needs only to examine the paths relevant to period 1 supply groups -- a task that, while still sizeable, is quite manageable with the aid of an efficient sort algorithm.

Refinements

Simulations of the prototype HPM and recent discussions (Klingman 1984) have suggested several improvements to the prototype formulation. These are briefly described below:

Single-Stage Specification

As noted earlier, the separation of the assignment of a DEP length from the assignment to an MOS was motivated because too many arcs in the network could cause ARCNET to exceed available core memory on the EPAS microcomputer. It now appears that an in-core/out-of-core (I/O) version of ARCNET will provide acceptable solution times, even for very large problems, and that such a code can be implemented on the EPAS microcomputer. For example, core requirements for I/O ARCNET are a function of the size of the node set, and a single-stage formulation of the HPM will reduce the number of nodes. Also this modification looks promising for several additional reasons:

- The combination of the DEP and MOS-assignment decisions onto a single AC-AU (or AC-AL) arc will more accurately mimic the decision process that actually occurs.
- The solution will provide the information needed to "track" the use of the DEP--a useful capability for policy analysis.
- Under a single-stage formulation, it will be necessary only to examine marginal costs in the first layer of the network to generate the ordered list for the SCM. This will greatly reduce the memory requirements for the post-processing operation.

Class Size Bounds and Stability Goals

It is anticipated that the structure currently used in Levels III and IV of the network to model class size bounds and inter-class stability in quality mixes will be replaced by a structure using artificial demands on each AU and AL node, matching artificial supplies on DMU and DML nodes, and a series of "backward" arcs linking

the two. These arcs will be capacitated and will carry costs that increase with the volume of the backward flow. This device will allow the elimination of both the multiple arcs in Level III, and the balance arcs in Level IV, while continuing to encourage a stable quality mix among classes. It will also allow relaxation of the excessively tight constraints imposed by the lower bounds on flows from AU and AL nodes to DMU and DML nodes. Finally, it will insure that the DM*-DMT flows in the solution reflect the true annual quality distribution attained.

Priorities

The possibility of applicant supplies insufficient to meet overall requirements will be addressed by the addition of a "supersource" allowing the network to draw, at a high cost, on a pool of "imaginary applicants" who are eligible for all MOS. This, in combination with an additional term in the cost function for the AC-AU (AL) arcs will allow shortfalls in supply to be dealt with in accordance with established policies.

Quantifying Human Judgment

When applicants meet with Army guidance counselors, judgments must be made to determine the skills in which they could best serve and determine which jobs are to be offered. This quantification is performed by the SCM.

Problem Statement

The SCM is constrained to processing applicants in the order in which they arrive, but it needs to have knowledge of future arrivals. Accordingly, the research for the SCM design focused on two issues:

- Interfacing with the HPM to provide a "look ahead" capability not otherwise available.
- Quantifying human judgment to determine the best person-job match.

HPM Interface

The SCM recommends MOS assignments on a sequential, case-by-case basis. The resulting assignments, while best suited for the applicant and the Army at a specific point in time, need to reflect movement toward the overall, optimal assignment patterns for the Army.

The need to "look ahead" is addressed by the SCM receiving from the HPM a list, ordered by HPM-assigned scores, of each supply group's recommended assignments to AIT classes. (Multiple AIT classes within the same time period are treated as one class.) (See the preceding discussion on the HPM for a definition of the generation of this ordered list.) The HPM score is then combined with SCM-generated scoring factors to determine the overall score for each PJM option.

Quantifying Judgment

The second problem is the selection of a methodology which best supports the person-job match process and recommends various MOS for which the applicant has a high probability of successful performance--both during and after training. The approach must consider both the applicant's unique attributes and the Army's current (and future) demands in determining the best possible matches.

SCM Methodology

Several methodologies were examined for use with the SCM, including:

- Policy Specification--a method for specifying interactions between two variables.
- Utility Theory--use of classical utility theory techniques to identify and quantify valid predictors of performance potential.
- Expert Systems--quantification of the, often intuitive, decisions which were used to make "good" assignments by "expert" guidance counselors.

- <u>Heuristic Simulations</u>—formulating a "worth" statistic based on factors which are felt to be good predictors of desirable attributes (performance, longevity, reenlistment potential, etc.).

<u>Policy Specification</u>

"Policy Specification" is a technique (Ward et al. 1977) implemented in the Air Force's Advanced Personnel Data System—Procurement Management Information System (APDS-PROMIS). There are two principal assumptions in policy specification:

- Factors involved in decision-making interact in a nonlinear, functional form.
- Managers can, at a minimum, quantify extreme points in this relationship.

Using these principles, the Air Force has developed a system in which managers define the "desirability" (payoff) of certain interactions; for example, the applicant's aptitude scores versus a job's difficulty, at extreme points (maximum difficulty—maximum aptitude, maximum difficulty—minimum aptitude, etc.) and at identifiable inflection points (e.g., aptitude equals difficulty). These values are then used to generate a table of intermediate points. The manager is asked to review and refine (by altering intermediate points) this table; the altered points are then used to generate a new table.

This iterative process continues until the manager is satisfied that the table adequately represents desired policy. The function which generated the tables is then used in the operational system, e.g., APDS-PROMIS, to quantify the relationships between applicants and jobs.

<u>Utility Theory</u>

An accurate classification of applicants to jobs, regardless of the final procedure involved, requires the identification of factors

which will accurately predict success while insuring that the Army's mission requirements are met. It is obvious that potential predictors can use dissimilar measures; e.g., dollar cost of training versus months of expected first term service.

This observation leads to the exploration of utility theory as a means to identify "pure" predictors and to ascertain the relationship among such predictors. Accordingly, the usefulness of this approach for the SCM was investigated. Several difficulties were identified:

- Correlation among independent variables. The independent variables available within the Army's data system appear to have a high intercorrelation, e.g., aptitude area scores, AFQT category, and expected months of first term service are all correlated.
- "Impure Predictors." Many of the independent variables are dependent on other factors. For example, MOS priority reflects not only the importance of the skill to the Army's mission (priority) but also the difficulty of filling the MOS and current manning ratio for the skill. As a result, the factors are not well suited to utility theory applications.
- Lack of Data. An attempt was made to design what might be called "pure" or valid predictors and gather data to investigate a potential scoring algorithm. However, such data were not available.

While each of these concerns might be overcome, a practical concern makes this undesirable. EPAS must be useable by the Army and needs to employ terms, policies, and data available to, and understood by, Army personnel. Variation should only happen if the system's performance could be greatly enhanced. Our simulations and the experience of other military services indicate that adequate performance may be obtained through other techniques. Futhermore, additional research to improve performance predictions is being developed elsewhere (Eaton and Goer 1983).

Expert Systems

A third approach is the use of some form of an expert system to quantify the decision process inherent in a "good" counselor.

Data from various Military Entrance Processing Stations (MEPS) indicate significant performance variation, e.g., percentage of quality applicants who actually sign Army contracts. The guidance counselors state that they have considerable influence on an applicant's choice of MOS and decision to enlist. This suggests that a properly formulated expert system could have significant impact on raising the overall level of performance at MEPS. Research supporting expert system's potential for EPAS is documented in Unger (1983) and Unger (1984).

Three areas of concern are involved in the application of an expert system in the SCM:

- What measures should be used to define a "good" counselor?
- What factors are involved in a "good" counselor making his decision?
- How should an expert system be employed within the framework of the SCM?

The application of expert systems in the SCM offers potential for enhancing the system's ability to accurately assign applicants. However, current work has been confined to preliminary investigation of key factors involved in guidance counselors' strategies for motivating applicants to join the Army.

Heuristic Simulation

The fourth approach involves selection of performance criteria, both traditional, e.g., predicted training success, and non-traditional, e.g., predicted length of service, which offer a high probability of forecasting desirable behavior. Each of these criteria are then

simulated and combined to generate a score for matching applicants to specific job openings.

The methodology is considered heuristic because there is no formal procedure for selecting which criteria are to be included. Instead, terms are selected based on intuitive judgment that selected criteria will be valid predictors.

Similarly, the method of combining the disparate measures is subject to a high degree of intuition. Criteria are usually weighted linearly, with the weights selected that appear to best implement desired policy. We are exploring more rigorous determination of weights, such as the use of optimization to select weights which would best fit a historical sample population to a desired set of requirements. Validation of selected measures is provided by using the EPAS Process Simulation System to generate classifications for different predictors and weights.

The measures to be used with this technique can be divided into two categories:

- Measures of Reservation Status. These measures capture information about the specific AIT class assignment being considered without regard to the applicant being processed.
- Applicant-Specific Measures. These measures are unique to the applicant—MOS combination being considered.

Reservation Status. This term describes factors about the current status of a job which are of particular concern to the Army. The types of information which might be included in this category include the number of AIT class seats as yet unfilled, the relative priority of applicant MOS, the difficulty of filling MOS, the time remaining to fill an MOS, and percent of total (annual) requirement which has been filled.

These measures are independent of the individual applicant and reflect those areas in which the Army might express the relative importance of filling an MOS and factors relating to how well the MOS is being filled. The "reservation status" measures allow the Army to define its policies and objectives regarding the filling of applicant training classes.

Applicant-Specific. These measures include all factors which define an individual applicant and his suitability for an MOS. Types of measures are personal, such as MOS preferences, and interactive, i.e., how well the characteristics match the MOS' requirements.

Structure of the SCM

None of these techniques dominates the others; each has certain desirable characteristics. The structure selected for the SCM, therefore, is an amalgamation of several of the techniques. The principal issues in the selection of the structure were:

- User understandability. The criteria must be in terms which the typical Army user would understand and for which data either existed or were easily attainable.
- System Responsiveness. The system structure must be responsive to changes in its environment.

  These changes include:
  - User-Initiated. Changes in Army policy such as the relative priority between combat arms and highly technical skills.
  - Environmental. Changes outside the control of the Army but which can affect the applicant flow. These might include changes in the economy or a change in the public's perception of the desirability of military service.

- **System Flexibility.** The system should remain flexible to the selection of different criteria reflecting further analysis and/or responding to changes in the operating environment.

With these considerations in mind, the structure selected was based on a heuristic simulation approach. A weighted, linear combination of the criteria is used to generate the person-job matches. (See Kroeker and Rafacz 1983.) Each measure is transformed to a score in a range of 0-1000 to facilitate weighted combination. (The precise technique used to transform an applicant measure is subject to independent analysis.)

Applicant criteria are selected based on terms which have been shown to be good measures of performance. Newer criteria will be included; however, as analysis indicates them to be desirable predictors.

Where appropriate, policy specification is used to formulate predictors based on multiple applicant criteria. Such formulations; however, are constrained to "single level" combinations (the independent variables will be directly measurable rather than being formed by earlier combinations).

We determined that an expert systems approach was not necessary at this stage of SCM design. However, expert systems are being investigated to help the guidance counselor best use the SCM recommendations to "sell" an applicant.

There are no current plans to include criteria developed from a utility theory approach because of three considerations: user understandability, system responsiveness, and system flexibility. While utility theory may provide a quantitative approach to the selection and weighting of factors, we believe these limitations would render it ineffective to any person-job matching decisions.

Simulation

Simulation will support EPAS development in two ways. It provides a means to replicate conditions external to EPAS and a means to evaluate various configurations of EPAS. In operation, the Army will be able to conduct "what if" exercises by varying the characteristics of the projected applicants or evaluating the effects of a change in policy, e.g., limits on the length of time applicants can remain in the DEP.

The Process Test System, described in Section III, was developed to provide a framework for these simulations. In addition to simulating the operation of the entire EPAS, it permits testing a specific module or various combinations of modules.

External Interfaces

The following external interfaces are simulated.

Guidance Counselor Interface

This simulates a guidance counselor entering an applicant's demographic and test score data, and using EPAS to recommend an MOS assignment.

Because the guidance counselor was difficult to simulate in detail, this interface has been reduced to the selection of a particular MOS on the list of MOS that are presented to the applicant. The following MOS selection options are available:

- The applicant always selects the "n"th entry from an ordered list of MOS where the first entry is the EPAS-determined best assignment.
- The applicant randomly selects from "n" entries starting at entry "m."
- The applicant randomly selects from "n" entries starting at entry "m" according to some predefined distribution.

Applicants for Enlistment

Historical data are used to simulate applicants, with various combinations of demographic characteristics and ASVAB scores, arriving on a seasonal basis. Various files can be generated to evaluate specific situations. For example, the following types of files have been generated (in all cases the specific applicant record is randomly selected from a historical applicant data base):

- Proportional. Applicant data are proportionally representative of historical applicant data base in terms of quality of the applicant but contain a smaller number of applicants.
- All High Quality. Data are proportionally representative of the high quality in the historical applicant data base.
- All Low Quality. Applicant data are proportionally representative of the low quality people in the applicant data base.
- Variable Mixtures. Applicant data proportions are user-defined.

Reservations System Interface

The Army reservation system performs the actual determination of MOS school seat availability and confirms acceptance of an applicant into an MOS. The EPAS interface to this system consists of the following simulated functions:

- The assessment of the availablity of a particular MOS and associated AIT class(es).
- The confirmation and assignment of an MOS to an applicant.

These interfaces will be simulated by the testbed itself. Files which are representative of the reservation system files can be developed by the user for the analysis of the EPAS modules. It is anticipated that in a future version of the testbed, the system interface can be exactly modeled to interface with the reservation system.

Internal Interfaces

The internal interfaces among the EPAS modules are simulated via data files. This is feasible because the modules were developed to be independent programs.

Methodology

The simulation methodology first evaluated each EPAS module as a separate entity simulating the external environment and its EPAS module interfaces. Several test cases for each module were developed, testing nominal as well as extreme internal/external conditions. These tested EPAS modules were then integrated into EPAS subsets, e.g., the HPM and SCM, with all other EPAS modules being simulated. These subsets were then tested using a wide range of interface conditions. Finally, all EPAS modules were integrated and tested.

The Process Test System generates all of the nominal and extreme test conditions. Several sets of test conditions were developed, representing user-selected test cases. These are used to evaluate the applicant modules and subsets. These test cases provide a basis on which to fine-tune the solution. Another set of test cases are being developed to use as the acceptance test cases for the EPAS. Additionally, special purpose test cases can be developed to determine how EPAS responds to a singular case.

Policy Analysis

EPAS can be used in a simulation mode to analyze important Army management problems. These include such issues as the scheduling of training plans, recruiting goals and incentive programs. The output

from these simulations can be statistically analyzed to determine the impact of management policies against such measures as job success, attrition, and reenlistment goals.

One of the first analyses performed was on the impact of EPAS compared to the current MOS allocation process. Some of the questions we sought to answer were:

- Can EPAS achieve substantial performance improvements against several goals simultaneously, or must one goal be achieved at the expense of others?
- Can overall improvements in performance be achieved without adversely penalizing particular segments of the Army?
- What value would changes in allocation policies provide the Army? Would these changes be substantial enough to justify the costs of overhauling computer systems and management procedures?

A series of simulation experiments were run using samples of accessions during 1981-82 to answer these questions. These experiments were designed accordingly:

1. Accessions were constrained to fill the same requirements actually filled.
2. All applicants chose an optimal assignment.
3. The objectives used were job performance (measured by SQT) and retention (measured by the probability of completing three years of service).

<u>Improvements Against Several Goals</u>

Figure 4 provides the results from one set of experiments (detailed results can be found in Nelson and Schmitz 1984). The simulations used the following objective functions:

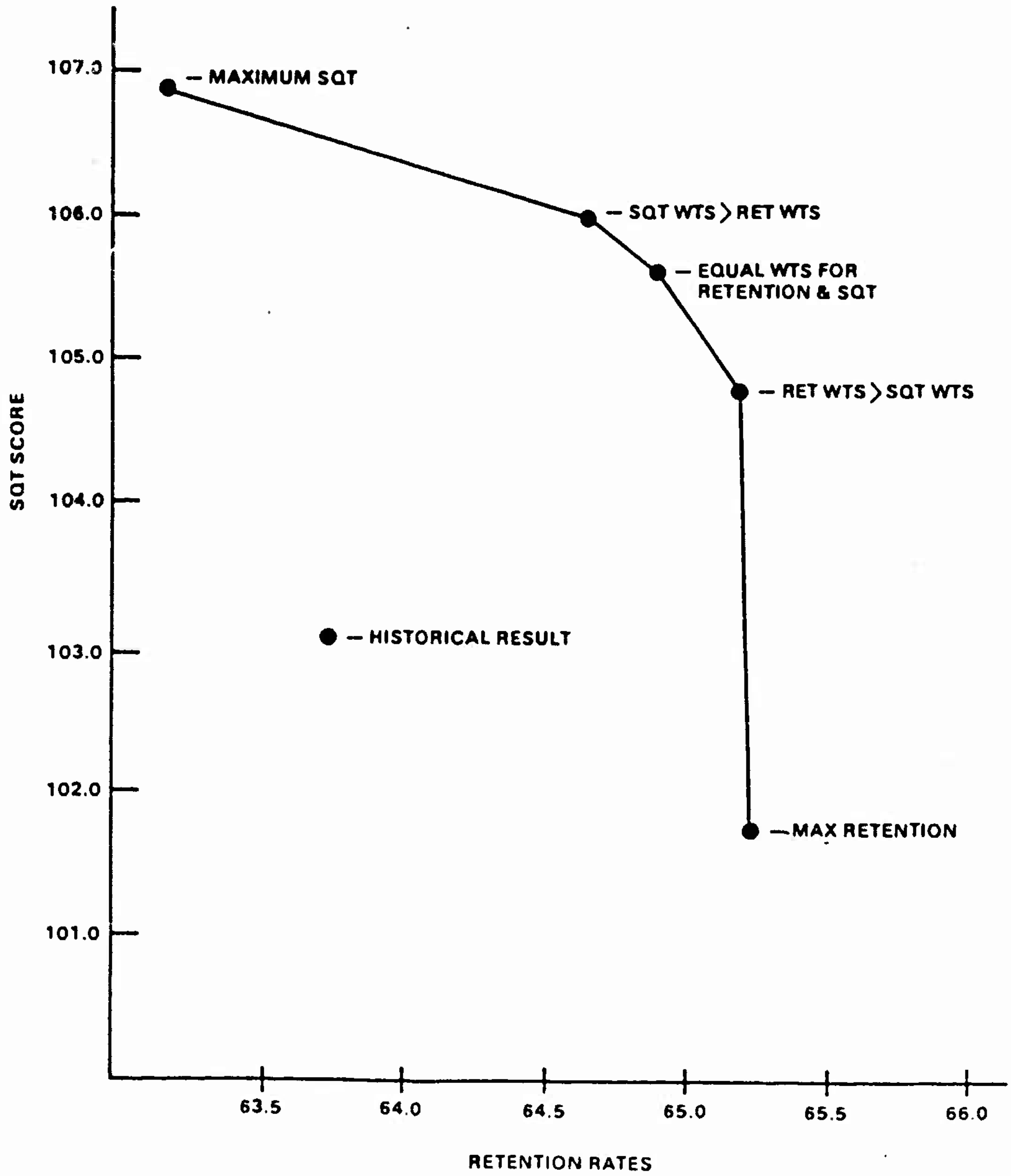

Figure 4. MOS Allocation Efficiency Frontier

- Historical assignment policy
- Maximizing job performance only (SQT)
- Maximizing retention only
- Maximizing retention and job performance with over 10 times greater weight on SQT
- Maximizing retention and job performance with over 10 times greater weight on retention
- Maximizing retention and job performance with equal weight on each objective

The maximization solutions in Figure 4 define a Pareto-optimal efficiency frontier. From this frontier it is evident that:

- It is possible to exceed current allocation policies in terms of both job performance and retention.
- The solution is sensitive to the inclusion of objectives, not the weights on those objectives.

As long as a goal was included in the objective function the EPAS solution produced a gain against that objective. Thus, there exists a large number of solutions that produce improvements in both objectives.

Distribution of Performance Gains

Another concern is the distribution of performance gains. For example, it may be undesirable to implement a system that generated aggregate performance increases only at the expense of lowering the quality in many MOS. Figure 5 presents the results from an allocation experiment against nine principal groupings of MOS. (See Table 1 for a description of the MOS in each MOS group.) This experiment demonstrated that it was possible to improve performance in all major job categories, not simply trade off performance in one area against another. (See Schmitz and Nelson 1984.)

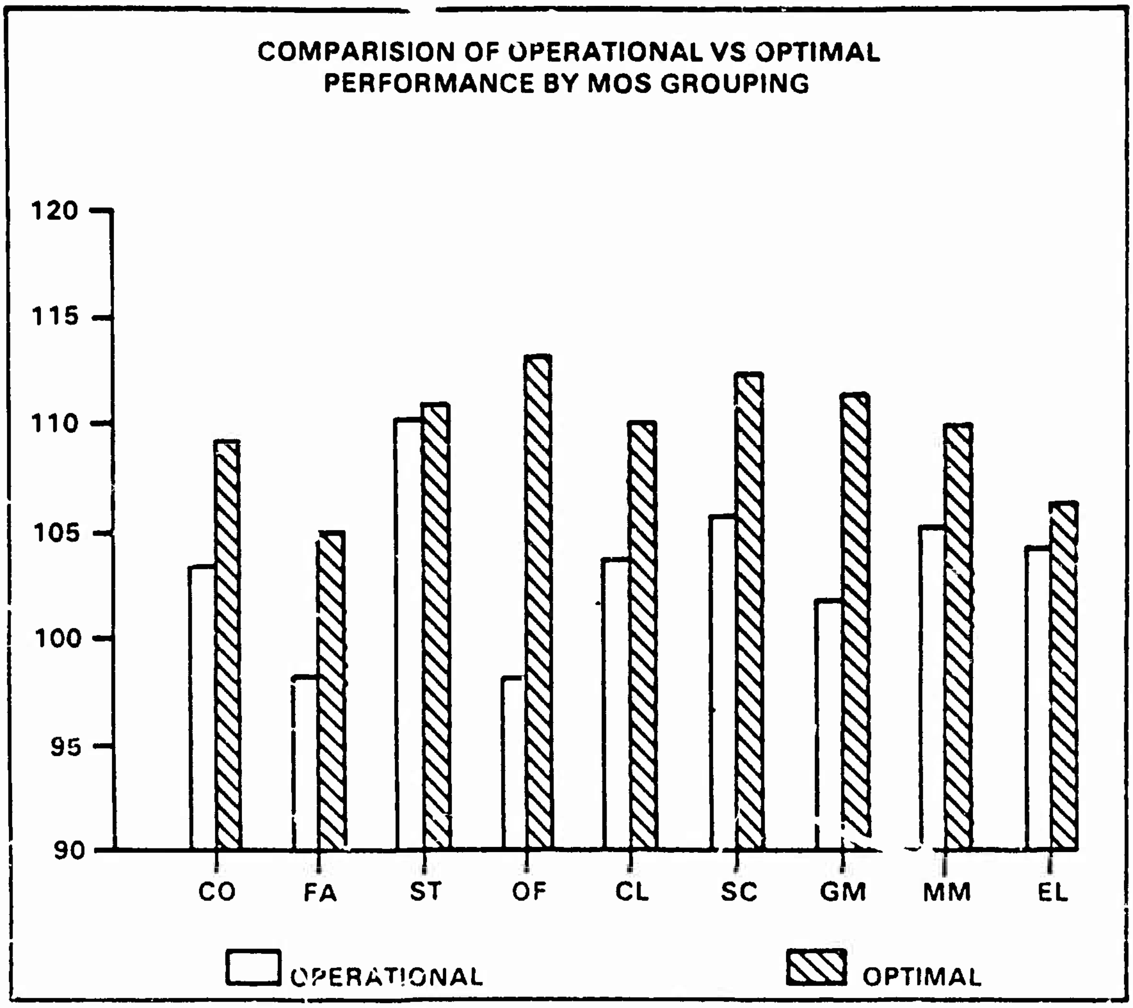

Figure 5. Comparison of Operational vs Optimal Performance by MOS Grouping

Value of EPAS

Finally, the Army wishes to know whether the improvements generated by EPAS justify its development costs. What benefit might it be to the Army to increase SQT performance by three points and retention by one percent?

Considerable work has been done on retention analysis. Generally, a cost of approximately $10,000 has been associated with each soldier who leaves before the end of his enlistment term (Eaton et al. 1982). Increasing retention by one percent would reduce attrition by 1400 in a 140,000 person accession cohort. This would produce a training cost savings of $14 million.

The value of job performance is difficult to measure in a military organization since there is no market value for output. However, the US Army, Congress, and the Department of Defense have recognized the value of having soldiers who can effectively operate today's weapons, and have developed programs providing educational benefits, enlistment bonuses and other incentives for high school graduates with above average intelligence who enlist in the Army. The performance gains for these high quality soldiers can be predicted from their entrance tests (Hanser and Grafton 1983).

EPAS would produce an SQT gain of three points. To achieve this increase with current allocation policies it would have required an enlistment cohort containing eight percent more Category I-IIIA recruits. Given a current marginal cost of $8700 to recruit an additional Category I-IIIA male (Armor et al. 1982) this SQT performance increase would have cost $97.4 million to achieve through recruiting.

The improvements in retention and job performance indicate that EPAS can substantially improve Army personnel management. Given an amortized development and operation cost of $2 million annually, EPAS will substantially benefit the Army. Other objectives, such as

reduced time sharing costs, more effective recruiting of talented applicants, and avoidance of critical training shortages will further enhance the value of EPAS to the Army.

III. ADP IMPLEMENTATION

EPAS is being developed on a Motorola 68000 microcomputer chip-based WICAT 160 microcomputer system. Our WICAT 160 system has the following hardware options:

- 2.5M Bytes RAM
- 474M Bytes Hard Disk
- 1M Byte Floppy Disk Drive
- 9 Track Cipher Tape Drive
- Floating Point Hardware Processor

The operating system is the WICAT Multi-user Control System (MCS), which is UNIX compatible. The initial EPAS construct was coded in APL to assess the initial feasibility of the approach and to evaluate various options and features. The current configuration is coded primarily in Pascal with segments of the HPM coded in FORTRAN 77. (The FORTRAN 77 coding was done to ensure compatability with the ARCNET network optimization code, which are coded in FORTRAN.)

The implementation of EPAS within the Process Test System is illustrated in Figure 6. Nine primary functions comprise the PTS:

- Module Execution Control and Feedback Monitor. This module is the controller of the system and executes all other EPAS and PTS modules based upon user request.
- User Interface Function. This module presents menus and screen formats, prompts for all values and generates appropriate help and error messages.
- Simulated Training Requirements Module Function. This module generates a demand file according to user specifications.
- Simulated Accession Module Function. This module generates a file of enlistment applicants according to user specifications.

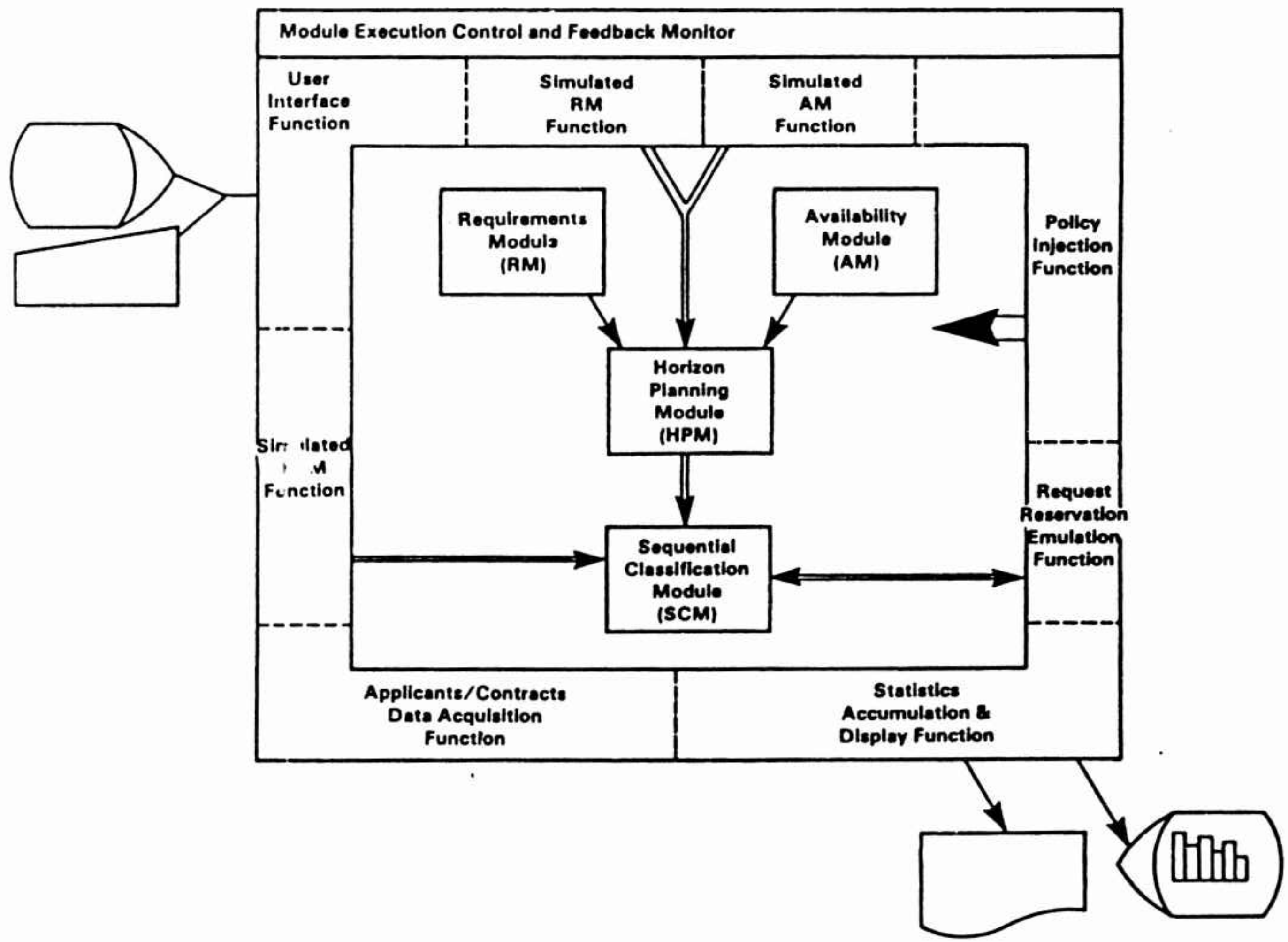

Figure 6. Process Test System - EPAS Testbed

- **Policy Injection Function.** This module (to be developed) will be used to modify policy parameters in all of the EPAS modules.
- **Army Reservation Emulation Function.** This module emulates AIT class seat availability and applicant reservations for MOS training.
- Statistics Accumulation and Display Function. This module generates statistical reports from the output of the EPAS modules.
- Applicants/Contracts Data Acquisition Function. This module generates an applicant/contract test data file based upon user-requested demographics, applicant quality, and MOS assignments to be used in the analysis of the SCM.
- Simulated HPM Function. This module simulates the operations of the HPM based on user specifications.

The PTS was developed to test EPAS in a total systems context. Using the PTS, applicant candidate EPAS components can be executed and evaluated, and the interface/interaction between components can be assessed. The PTS is coded in Pascal. Its "user friendly" characteristics include choices presented in menus and prompts and validity checks for all required information. Appropriate error and help messages are available.

Based upon user specifications, PTS generates the EPAS environment, executes the EPAS modules, and tabulates the results which are stored in data files and subsequently printed. All EPAS modules have been designed and implemented as separate programs/tasks, ensuring an uncoupling of each EPAS module from the PTS and from each other. This uncoupling easily allows for the insertion or deletion of candidate modules from the EPAS construct thus allowing the evaluation of candidate modules individually or in combination with others. In order to execute these modules, the PTS spawns each module as a separate process with all communication being performed through data files and (in a forthcoming version) interprocess mail.

The EPAS environment is simulated by the following files generated by the PTS:

- Applicant File. Army applicant records consisting of demographic data, test scores, and physical results. The PTS can generate representative or special purpose files.
- School File. AIT class dates, availability restrictions, and capacities.
- MOS Requirements File. Specific MOS qualifying score requirements as well as MOS quality goals.

Other files through which the EPAS modules communicate include:

- Availability Module-HPM Interface File. Contains forecasted supply group counts.
- HPM-SCM Interface File. Contains a matrix of each supply group's rank ordered list of recommended AIT assignments.
- SCM-PTS Interface File. Contains the results of the applicant to MCS matching process.

Availability Module

The current version of the Availability Module uses the USAREC's goals for contracts as a forecast of applicant supply at the mission box level. These missions are then multiplied by monthly supply group factors to arrive at the monthly forecasts of contracts by supply groups. Additionally, the forecast of contracts of male, high school graduates in Categories I-IIIA are split into upper and lower quartiles.

Two files are generated by the Availability Module. A file for the HPM defines each supply group and gives its monthly forecasts. A file for the SCM identifies the supply group to which a particular applicant belongs.

Horizon Planning Module

A prototype version of the HPM has been implemented on the WICAT 160 with three submodules. One submodule, the preprocessor, is written in Pascal, whereas the others are in FORTRAN.

Characteristics of the Experimental Version

The prototype HPM uses a representative subset of 15 supply groups as the supplies for the network and 10 MOS as the demands. Currently the problem is solved across a horizon of 12 time periods of a month each. This results in a network problem of size 750 nodes and 3500 arcs. The DEF policy modeled has a maximum length of six months.

HPM Submodule

A preprocessor handles all user interaction for the entire HPM, and also generates the problem file for the network code. The network code then solves the problem and passes the optimal solution to the postprocessor. The postprocessor then produces the ordered lists for the SCM of each supply group's AIT class assignments to be passed to the SCM. All linkages between the segments of the HPM are done via files.

Preprocessor

The preprocessor allows the user to specify the supply and demand files used in building the problem file. It also asks for linear weights for a combination function of predicted SQT scores and ET values to measure the relative value of a particular type of applicant being assigned to a specific MOS. The number of AIT class assignments for each supply group which the HPM passes to the SCM can also be controlled by the user.

Network Code

In the prototype HPM the ARCNET pure network solution code is used to solve the network. For the full-size model of all MOS and supply groups, the network problem will be too large to fit into main memory on

the WICAT. Thus, we are obtaining an in-core/out-of-core version of ARCNET that stores only the problem basis data structures in-core with the arc data residing on disk and being paged in as needed. Despite the 2.5 megabyte limitation on the WICAT, this should eliminate core memory restrictions as the network becomes very large, but at a cost of additional computation time.

Postprocessor

This submodule, written in FORTRAN for compatibility with the network code, produces the ordered list of AIT classs assignments for applicants from each supply group, based on the marginal costs of the arcs not in the optimal assignment. This list is used on the SCM scoring routines and is passed to the SCM via a keyed file. The postprocessor also produces reports which summarize the solution from the network and permit tracking of MOS assignment and DEP behavior for each supply group.

Results

Testing of the HPM verifies that when better qualified applicants are available, it inhibits marginally qualified applicants from being assigned to technical MOS.

Under the current formulation, class size is tightly constrained and is therefore met by substituting high quality applicants in the same MOS and same time period to fill a shortage of low quality applicants, and vice versa. These constraints may be loosened in later versions. The formulation is also designed to meet the Army-specified percentage of high quality applicants in each MOS annually. In addition, it attempts to assign an even flow of high quality people into the AIT classes, over time, to alleviate promotability gaps.

Sequential Classification Module

The ADP implementation of the SCM performs three related functions: a determination of eligibility, the actual scoring, and presentation of the resulting recommendations.

Determination of Eligibility

Each MOS has minimum eligibility requirements. Therefore, the first function to be performed is to determine if an applicant is minimally qualified to serve in an MOS. In the prototype SCM, two factors are checked for eligibility:

- Combat Arms Exclusion. Female applicants are prohibited from serving in any MOS which has a direct combat-related requirement. The SCM utilizes a "combat arms" flag in the definition of an MOS, insuring that no females are considered for jobs in the combat arms arena.
- Minimum Aptitude Requirements. Each MOS has up to three aptitude areas and is assigned a minimum score for each. Failure to get above the minimum qualifying score renders the applicant ineligible for that MOS.

As implementation of the SCM continues, additional eligibility criteria will be added such as: citizenship, physical factors, and educational requirements.

Scoring Routines

As described in Section II, the SCM uses a linearly weighted algorithm to determine the desirability of assigning an applicant to a MOS. The structure of the SCM scoring routines is shown in Figure 7, and consists of three submodules:

- Interface Submodule. This submodule provides the interaction between the global solution generated by the HPM and the local, applicant-specific assignment to be generated by the SCM.
- Reservation Status. This submodule captures information about the specific jobs in question without regard to the applicant being processed.
- applicant Specific. This submodule relates the information unique to the applicant being considered to the specific jobs.

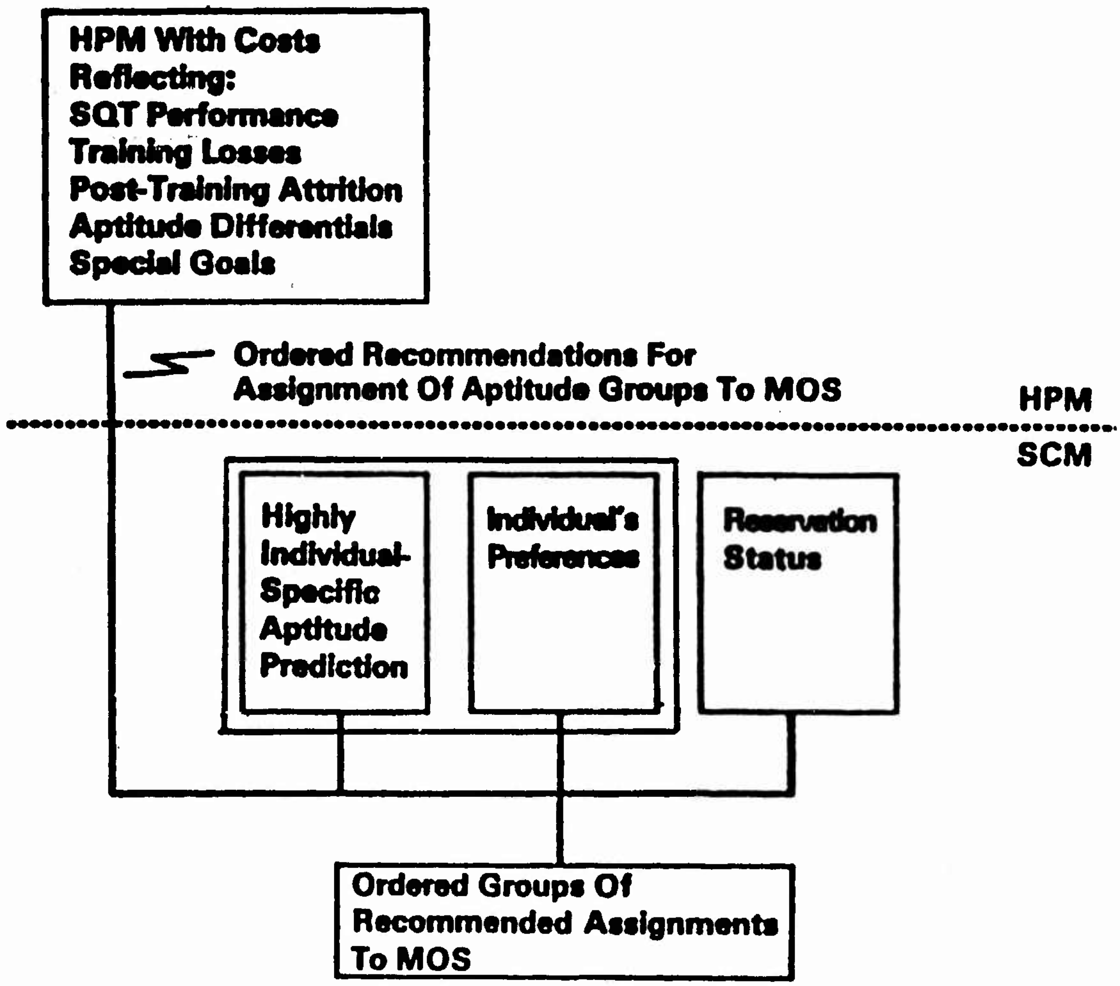

Figure 7. Structure of Sequential Classification Module

Interface Submodule

A key feature of EPAS is its ability to "look ahead" at both supply and demand to generate assignments which will optimally meet the Army's policies and job requirements. Optimal allocation of supply groups to MOS is accomplished in the HPM. If this optimal allocation is to have an effect on the assignments of applicants as they present themselves to the system, some means must exist for communicating the HPM's optimal configuration to the SCM.

Since the Army cannot force an applicant to accept an assignment the specific optimal solution is of limited usefulness. (In case of a reinstitution of the draft, the optimal solution could be used directly as the Army would be able to dictate actual assignments to draftees.) Instead, some means of "recommending" assignments based on an ordering of how close they come to the optimal was required. This need was met by examining the marginal costs along non-optimal paths in the network, and forming an ordered list of alternate assignments.

The ordered list, generated by the Postprocessor Submodule of the HPM, is passed to the SCM as a file. Applicant records within the file are keyed by supply group, MOS, availability date, and AIT class start date. The SCM, as it scores an applicant against a specific job, constructs the key and accesses the HPM file. (If a record is not found, a value of zero is assigned.) The HPM record will contain a value indicating the desirability of the assignment where 1000 is optimal.

Reservation Status

This submodule permits defining policies and objectives regarding the filling of specific AIT classes. In the Prototype SCM the only factor from this category which has been included is how many class seats have been filled.

Applicant-Specific

This submodule includes those factors which define an individual applicant and his suitability for an MOS. Two factors have been implemented in the prototype version: predicted SQT score and ET.

Predicted SQT. The SQT is administered to Army enlisted personnel to determine how well they are performing in their current speciality. Clearly, it would be desirable to assign personnel to the skill in which their predicted performance would be maximized. Implementation in the initial version of the SCM was based on research by Schmitz and Nelson (1984) in which the predicted SQT is defined as a function of the applicant's scores in the aptitude area with which the MOS is associated. The applicant's composite scores are read and multiplied by the appropriate factor to generate the predicted SQT.

Estimated Term of Service. ET is defined as the number of months an applicant of the type being processed can be expected to serve in his initial term of service. The ET computations are based on analysis performed by Baldwin (1983). He defines the expected months of first term service as the area under a Weibull distribution whose shape is defined by a series of demographic (education), economic (unemployment rate), and service (term of enlistment) factors.

We developed unique ETs for each MOS in the Prototype EPAS. The shape of the function is estimated based on the characteristics of the applicant under consideration and the resulting function is integrated to generate the ET.

Presentation of Results

Each applicant is scored against all jobs for which he is eligible. The resulting scores (and the jobs with which they are associated) are written to a scratch file as they are generated. When all jobs have been evaluated, the scratch file is sorted in descending order.

An MOS is then selected from the ordered list either manually (operational mode) or by the computer (policy analysis mode). All dynamic fields, e.g., number of class seats filled, are automatically updated and processing continues with the next applicant.

IV. EXAMPLE RESULTS

The following results were produced using the prototype version (Version 1.2) of the EPAS Process Test System. The PTS executed the HPM and SCM separately and together, as a system.

The HPM was executed with the following restrictions:

- The weighting factors for ET and SQT in the cost computations for the network arcs were equal.
- The DEP policy was restricted to a maximum of 6 months.
- The top thirty choices of AIT class assignments were transferred to the SCM (via data file)

Several applicant files were generated to show the differentiability of the SCM to various input scenarios. Each of the applicant files contained about 500 applicants randomly selected from a file of approximately 50,000 applicants. Restrictions on the applicants selected were:

- Applicants had completed a physical and had signed an enlistment contract.
- All ASVAB scores had to be available and valid.

The following quality mixes of applicants were selected for each file [file identification]:

- Proportional to actual population [PRO500]
- All high quality people (Category I through IIIA) [HI500]
- All low quality people (Categories IIIB and IV) [LO500]
- Mix of 10% high quality and 90% low quality [AMIX500]
- Mix of 20% high quality and 80% low quality [BMIX500]
- Mix of 50% high quality and 50% low quality [CMIX500]

Further restrictions were placed on the AIT class file to allow only five applicants per month for a period of 14 months (except for MOS 11X which allowed 100 enlistees in the last period). This was done to verify that the SCM could function in a mode of restrictive class seat openings.

HPM Results

The HPM network code reached an optimal solution. The class size goals were met across all AIT classes in all time periods. In addition, the annual MOS quality distribution goals were met. See Section II for an explanation of these goals.

SCM Results

The SCM was executed separately for each of the applicant files. The MOS requirements, AIT class seat availability and input from the HPM output file were fixed. The projected behavior results of the PRO500 file run, the HI500 file run and the CMIX500 file run are presented in Figures 8-10. They indicate an increase in both the mean projected ET and SQT for those applicants assigned by the SCM compared to the average ET and SQT of the actual assignments.

See Figure 8, which depicts the results obtained from using the PRO500 applicant population. Under the columns labeled "Projected ET in Months":

- The column headed "SCM" gives the anticipated ET of the population assigned by the SCM.
- The column headed "AVERAGE" gives the ET of the applicants who were actually assigned to the MOS.
- The column headed "REASSIGNED" indicates the anticipated ET of the applicants assigned this MOS by the SCM based on the MOS to which they were actually assigned.

PROJECTED BEHAVIOR

MOS	INVENTORIES HPM	SCM	ACTUAL	PROJECTED REENLISTMENT RATES HPM	SCM	MOSLS	PROJECTED E(t) IN MONTHS SCM	REASSIGNED	AVERAGE	PROJECTED SQT RANGE:40-150 SCM	REASSIGNED	AVERAGE
05C	2796	32	28	0.3231	0.2965	0.1973	30.09	29.29	30.79	109.3	107.9	104.6
11X	25878	58	191	0.2940	0.3056	0.3767	29.30	30.67	29.33	97.3	98.5	102.6
13B	11347	57	58	0.2940	0.2991	0.5211	31.16	30.58	31.23	99.0	99.4	100.4
31M	3276	60	23	0.2400	0.2732	0.3091	29.66	29.90	30.31	110.5	105.7	107.7
63B	6592	56	10	0.2952	0.2060	0.2004	41.64	30.69	39.09	116.6	109.5	101.9
64C	6400	60	31	0.2970	0.2993	0.3009	30.64	29.92	29.01	99.0	98.5	99.6
67N	776	26	6	0.2000	0.2059	0.1055	29.37	30.34	30.03	109.7	107.9	106.4
71L	8871	64	59	0.3314	0.3302	0.4697	29.37	29.05	29.94	110.9	105.0	110.0
91B	5203	27	41	0.2046	0.2076	0.3090	29.12	29.97	27.62	106.7	104.2	103.5
95B	8367	60	53	0.2000	0.2040	0.3350	32.32	31.02	30.91	111.1	107.2	107.5

Figure 8. PRO500 File - Projected Behavior Results

PROJECTED BEHAVIOR

MOS	INVENTORIES HPM	SCM	ACTUAL	PROJECTED REENLISTMENT RATES HPM	SCM	MOSLS	PROJECTED E(t) IN MONTHS SCM	REASSIGNED	AVERAGE	PROJECTED SQT RANGE:40-150 SCM	REASSIGNED	AVERAGE
05C	2796	40	36	0.3231	0.2962	0.1973	30.60	28.43	30.95	111.5	107.0	107.4
11X	25078	27	107	0.2940	0.2000	0.3767	29.49	30.13	29.35	106.3	107.4	105.7
13B	11347	46	44	0.2940	0.2036	0.5211	31.29	30.67	30.92	104.0	104.4	105.6
31M	3276	60	23	0.2400	0.2662	0.3091	29.29	29.57	29.41	110.6	106.2	107.0
63B	6592	67	15	0.2952	0.2030	0.2004	41.40	30.97	39.94	120.0	110.9	107.9
64C	6400	42	19	0.2970	0.2000	0.3009	30.40	30.53	29.59	103.3	104.7	102.7
67N	776	39	7	0.2000	0.2037	0.1055	30.12	30.75	29.72	110.7	107.3	109.0
71L	8871	67	55	0.3314	0.3026	0.4697	29.25	20.24	29.03	114.0	107.3	112.3
91B	5203	34	47	0.2046	0.2029	0.3090	30.11	30.65	27.66	110.1	106.1	106.6
95B	8367	60	65	0.2090	0.2030	0.3350	32.30	30.90	31.02	111.6	106.9	107.7

Figure 9. HI500 File - Projected Behavior Results

PROJECTED BEHAVIOR

MOS	INVENTORIES HPM	SCM	ACTUAL	PROJECTED REENLISTMENT RATES HPM	SCM	MOSLS	PROJECTED E(t) IN MONTHS SCM	REASSIGNED	AVERAGE	PROJECTED SQT RANGE:40-150 SCM	REASSIGNED	AVERAGE
05C	2796	20	27	0.3231	0.3036	0.1973	30.62	29.21	30.70	107.5	106.3	104.7
11X	25078	51	194	0.2940	0.3065	0.3767	29.36	30.51	29.19	97.5	98.0	101.1
13B	11347	75	62	0.2940	0.3009	0.5211	30.92	30.31	31.15	98.9	98.2	99.2
31M	3276	57	23	0.2400	0.2703	0.3091	29.91	30.02	30.06	109.7	105.6	106.9
63B	6592	58	19	0.2952	0.2863	0.2004	41.54	30.79	39.71	114.0	108.0	100.9
64C	6400	70	34	0.2970	0.3041	0.3009	30.43	30.01	29.70	98.3	98.3	98.8
67N	776	23	6	0.2000	0.2073	0.1055	29.57	30.74	30.03	100.0	106.3	106.4
71L	8871	62	54	0.3314	0.3305	0.4697	29.11	20.79	29.01	109.2	104.1	109.0
91B	5203	20	37	0.2046	0.2940	0.3090	28.98	29.18	27.67	104.0	103.0	103.0
95B	8367	56	44	0.2000	0.2060	0.3350	32.29	31.30	31.27	109.6	105.6	107.3

Figure 10. CMIX500 File - Projected Behavior Results

For example, an applicant assigned to the 05C MOS by the SCM may have actually been assigned 11X; in the "REASSIGNED" column, his ET is based on the 11X MOS.

Comparing the SCM column to the REASSIGNED column indicates the potential change in performance for the applicants; comparing the SCM column to the AVERAGE column indicates the expected change in performance for the MOS. Using the 05C MOS as an example, one can see that the SCM assignments show increased ET, for both the individual applicants and the MOS. This has the significant effect of both raising the experience level of the skill (as applicants serve more time in the skill) and of reducing long-range recruiting requirements (as applicants spend more time in the service).

This behavior pattern, while not universal, is consistent for the test MOS using ET, SQT, and reenlistment rates as measures of predicted performance. This was also true for both of the other sample populations (HI500 and CMIX500, Figures 9 and 10, respectively).

The SCM also responded correctly to the constrained school seat situation in that applicants were assigned appropriate lengths of DEP time. The DEP report for the PRO500 report is included as Figure 11 for reference.

Overall Results

The results of the EPAS analyses and simulations indicate that the methodologies employed can yield improved performance of Army enlistees by changing the assignment patterns for a given population. Army personnel experts anticipate these improvements in performance to be the same as could be expected by recruiting additional numbers of high quality personnel, without the additional costs involved in attracting and contracting this limited resource.

DEP PERIOD AVERAGES

	HS MALE		HSS MALE		NHS MALE		HS FEMALE		HSS FEMALE		NHS FEMALE		TOTAL
	1-3A	3B-4	1-3A	3B-4	1-3A	3B-4	1-3A	3B-4	1-3A	3B-4	1-3A	3B-4	
05C	37.4	51.0	0.0	0.0	30.0	0.0	31.0	0.0	0.0	0.0	0.0	0.0	39.4
11X	30.0	43.7	30.0	01.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.4
13B	29.4	49.6	0.0	61.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.6
31A	33.9	40.7	45.0	61.0	30.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	35.0
63B	33.4	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.4
64C	30.3	44.0	61.0	53.5	31.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.0
67N	30.9	30.0	30.5	61.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.5
71L	38.2	65.7	0.0	0.0	0.0	0.0	52.3	51.4	31.0	0.0	0.0	0.0	50.0
91B	30.7	31.0	30.3	62.0	0.0	0.0	31.0	0.0	0.0	0.0	0.0	0.0	35.0
95B	35.6	53.0	74.3	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	41.4

Figure 11. PRO500 File - DEP Report (in days)

The EPAS approach gives all indications of providing a cost effective, state-of-the-art solution to the problem of personnel allocation on a microcomputer-based system. Since this is only a prototype of the system, it is anticipated that more pronounced results can be achieved by further analysis of the problem, the investigation of alternative methodologies, and more fine-tuning of the algorithms.

REFERENCES

Armor, D.J., R.L. Fernandez, K. Bers, and D. Schwarzbach, Recruit Aptitudes and Army Job Performance, Rand Report R-2874MRAL, 1982.

Baldwin, R., Jr., "Army Recruit Survival Function: Estimation and Strategy for Use," PhD dissertation, Massachusetts Institute of Technology, March 1983.

Charnes, A. and W.W. Cooper, Management Models and Industrial Applications of Linear Programming, John Wiley and Sons, Inc., New York, 1961.

Charnes A., W.W. Cooper, R.J. Niehaus, and A. Stedry, "Static and Dynamic Assignment Models with Multiple Objectives, and Some Remarks on Organization Design," in Studies in Manpower Planning, Office of Civilian Manpower Management, Department of the Navy, Washington, D.C., 1972.

Dale, C. and C. Gilroy, "The Effect of the Business Cycle on the Size and Composition of the U.S. Army," Atlantic Economic Journal, Vol XI, No. 1., March 1983.

Dunnette, M.D., Personnel Selection and Placement, Wadsworth Publishing Co., Inc., Belmont, CA, 1966.

Eaton, N.K., and M.H. Goer, Improving The Selection, Classification, and Utilization of Army Enlisted Personnel: Technical Appendix to the Annual Report, ARI Research Note 83-37, October 1983.

Eaton, N.K., M. Weltin, and H. Wing, Validity of the Military Applicant Profile for Predicting Early Attrition in Different Educational, Age, and Racial Groups, Technical Report 567, ARI, Alexandria, VA, 1982.

Ford, L.R. and D.R. Fulkerson, Flows in Networks, Princeton University Press, Princeton, New Jersey, 1962.

Hanser, L.M. and F.C. Grafton, Predicting Job Proficiency in the Army: Race, Sex, and Education, Working Paper, ARI, Alexandria, VA, 1983.

Hatch, R.C., "Development of Optimal Allocation Algorithms for Personnel Assignment," in A.R. Smith (Ed.) Models of Manpower Systems, New York: American Elsevier, 1971.

Hillier, F.S. and G.J. Lieberman, Introduction to Operations Research, Holden, Day, Inc, San Francisco, 1967.

Horne, D. An Economic Analysis of Army Enlistment Supply, ARI Working Paper, May 1984.

Hunter, J.E. and F.L. Schmidt, "Fitting People to Jobs: The Impact of Personnel Selection on National Productivity," in Human Performance and Productivity: Human Capability Assessment, Earlbaum, 1982.

Klingman, D.D., Meeting at Analysis, Research and Computation, Inc., Austin, TX, April 5-6, 1984.

Kroeker, L.P. and B.A. Rafacz, Classification and Assignment within PRIDE (CLASP): A Recruit Assignment Model, Navy Personnel Research and Development Center TR 84-9, San Diego, CA, November 1983.

Kuhn, H.W., "The Hungarian Method for the Assignment Problem," Naval Research Logistics Quarterly 2, 1955, pp. 83-97.

McWhite, P., "EPAS Completed Systems Analysis Report," General Research Corporation Report 1317-07-83-CR, September 1983.

Moore, D., E.J. Schmitz, P. McWhite, and J. Allen, "Forecasting Long Term Enlistment Contracts for MOS Allocation," General Research Corporation Report PSO-83-1317-30, September 1983.

Moore, D., E.J. Schmitz, and P. McWhite, "The Categorization of Personnel Supply for MOS Allocation," General Research Report PSO-83-1317-31, September 1983.

Nelson, A. and E.J. Schmitz, "Multiobjective Personnel Allocation Planning," Working Paper, ARI, Alexandria, VA, July 1984.

Schmitz, E.J. and A. Nelson, "The Allocation of Army Personnel to MOS," Technical Report, ARI, Alexandria, VA, June 1983.

Schmitz, E.J. and A. Nelson, "Analysis of Army Enlistment Processing" Working Paper, ARI, Alexandria, VA, June 1984.

Unger, K.W., "A Conceptual Approach for Developing an Expert System for Army Recruit Classification to an MOS," General Research Report PSO-83-1317-28, September 1983.

Unger, K.W., "Identification of Interviewing Techniques Used by Experienced Army Guidance Counselors," General Research Report PSO-83-1317-35, March 1984.

Ward, J.H., Jr., "Creating Mathematical Models of Judgment Processes: from Policy-Capturing to Policy-Specifying," Air Force Human Resources Laboratory Report AFHRL-TR-77-47, August 1977.